Delft University of Technology

Document Version
Final published version

Licence
CC BY-NC-ND

Citation (APA)
Bleser, J., Vreugdenhil, H., Hasan, S., Leung, N., & Karstens, S. (2026). Assessing stakeholder readiness levels for innovation adoption in river management: flexible groynes in the Netherlands. *International Journal of River Basin Management*. https://doi.org/10.1080/15715124.2026.2702078

Important note
To cite this publication, please use the final published version (if applicable).
Please check the document version above.

Copyright
In case the licence states “Dutch Copyright Act (Article 25fa)”, this publication was made available Green Open Access via the TU Delft Institutional Repository pursuant to Dutch Copyright Act (Article 25fa, the Taverne amendment). This provision does not affect copyright ownership.
Unless copyright is transferred by contract or statute, it remains with the copyright holder.

Sharing and reuse
Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

Takedown policy
Please contact us and provide details if you believe this document breaches copyrights.
We will remove access to the work immediately and investigate your claim.

This work is downloaded from Delft University of Technology.

International Journal of River Basin Management



ISSN: 1571-5124 (Print) 1814-2060 (Online) Journal homepage: www.tandfonline.com/journals/trbm20

Assessing stakeholder readiness levels for innovation adoption in river management: flexible groynes in the Netherlands

Julia Bleser, Heleen Vreugdenhil , Shahnoor Hasan , Nick Leung & Sonja Karstens

To cite this article: Julia Bleser, Heleen Vreugdenhil , Shahnoor Hasan , Nick Leung & Sonja Karstens (29 Sep 2026): Assessing stakeholder readiness levels for innovation adoption in river management: flexible groynes in the Netherlands, International Journal of River Basin Management, DOI: 10.1080/15715124.2026.2702078

To link to this article: https://doi.org/10.1080/15715124.2026.2702078

© 2026 Stichting Deltares. Published by Informa UK Limited, trading as Taylor & Francis Group

View supplementary material

Published online: 29 Sep 2026.

Submit your article to this journal

Article views: 125

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=trbm20

INTERNATIONAL JOURNAL OF RIVER BASIN MANAGEMENT
https://doi.org/10.1080/15715124.2026.2702078

Taylor & Francis
by informa

OPEN ACCESS Check for updates

Assessing stakeholder readiness levels for innovation adoption in river management: flexible groynes in the Netherlands

Julia Bleser [a], Heleen Vreugdenhil[a,b], Shahnoor Hasan[a], Nick Leung[a] and Sonja Karstens[c]

[a]Deltares, Delft, The Netherlands; [b]Faculty of Technology, Policy and Management, Delft University of Technology, Delft, The Netherlands; [c]Rijkswaterstaat, Water, Traffic and Environment (WVL), Ministry of Infrastructure and Water Management, Lelystad, The Netherlands

ABSTRACT

Innovations in river management often stall at the transition from pilot to practice due to stakeholder hesitation, financial uncertainty, and regulatory inertia. This paper examines the usefulness of the Stakeholder Readiness Level (SRL) framework in river management as a decision-support and learning tool for guiding the transition from pilot implementation to broader application, using the case of flexible groynes in the Netherlands. The SRL tool complements technical evaluations by systematically assessing stakeholder perceptions across five adoption-relevant dimensions: Value, Commitment & Support, Costs, Feasibility, and Risks. Data were collected between 2020 and 2024 through structured interviews and group polling with government, research, and market actors. Results indicate that, despite acknowledging technical feasibility, progress toward adoption was constrained by unresolved cost structures and business-model arrangements, internal organisational resistance, and perceived regulatory and procedural misfit. Over time, most stakeholders converged toward higher readiness, though unevenly: contractors improved once financing options clarified, while the research institute retained concerns about internal issues, including unclear investment readiness, limited organisational alignment, and a lack of a lead partner for implementation. The SRL assessment tool proved useful as (1) a diagnostic instrument to surface adoption bottlenecks and specify follow-up actions, and (2) a reflexive platform for cross-organisational dialogue and learning. Embedding SRL assessments in collaborative environments such as Learning Spaces can help facilitate the transition of sustainable river innovations from experimentation to systemic practice.

ARTICLE HISTORY
Received 16 January 2026
Accepted 7 July 2026

ASSOCIATE EDITOR
Martínez-Santos, Pedro

KEYWORDS
Sustainable river management; innovation readiness; stakeholder readiness; co-creation; living labs; pilot-to-practice transition

Introduction

River basin management in Europe faces intensifying pressures from climate change, urbanisation, and evolving societal expectations. These pressures have reinforced the need for innovative river measures that not only perform hydraulically and ecologically, but can also be embedded in existing governance, financing, and maintenance regimes (Pielke et al. 2007, IPCC 2013 Kovats et al. 2014,). Yet, despite growing recognition of the need for adaptation, a persistent gap remains between awareness and implementation (Hall and Persson 2018, Lenaerts et al. 2022).

In the Netherlands, this gap often stems from misalignments between innovation goals and stakeholder priorities, commitment, and adoption (Vreugdenhil et al. 2010, Offermans and Cörvers 2012 Jong and van den Brink 2017,, Chu et al. 2025). Existing governance structures favour traditional engineering approaches, reinforcing path dependency and limiting stakeholder-driven innovation (Offermans et al. 2011 van den Brink et al. 2011, Jong and van den Brink 2017,). These challenges are not unique to the Netherlands but echo wider gaps in innovation adoption frameworks. River management has increasingly become a multi-actor domain in which government agencies, researchers, and market parties jointly shape innovation trajectories, making collaboration and alignment across organisations a prerequisite for adoption.

Many water management innovations stall after successful pilots. This 'pilot paradox' occurs when technical feasibility is demonstrated, but institutional, financial, or regulatory conditions for adoption are not yet in place (Vreugdenhil et al. 2010, Van Buuren et al. 2019). Pilots provide important learning environments but may also isolate innovations from mainstream processes (Van Buuren et al. 2019). Assessing this stakeholder and institutional readiness is therefore critical for understanding whether and how innovations can move beyond the pilot phase.

The Technology Readiness Level (TRL) framework is widely used to assess technological maturity, but gives limited attention to institutional, financial and

CONTACT Julia Bleser julia.bleser@deltares.nl Department of Ecology and Water Quality, Deltares, Boussinesqweg 1, Delft 2629 HV, The Netherlands

Supplemental data for this article can be accessed online at https://doi.org/10.1080/15715124.2026.2702078.

© 2026 Stichting Deltares. Published by Informa UK Limited, trading as Taylor & Francis Group
This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives License (http://creativecommons.org/licenses/by-nc-nd/4.0/), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited, and is not altered, transformed, or built upon in any way. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

societal conditions shaping adoption (ESA 2009, Olechowski et al. 2015,, Webster and Gardner 2019 Bates and Clausen 2020). Complementary approaches have emerged that foreground governance, behaviour and societal values, yet many remain generic rather than tailored to infrastructure-based, multi-actor river innovations (see Table 1 and Supplementary Table S1). This paper addresses that gap by applying the Stakeholder Readiness Level (SRL) framework to assess adoption readiness beyond technical performance.

This study focuses on the flexible groyne pilot in the IJssel River within the Dutch Learning Spaces programme, where government, research and market actors co-design and evaluate river innovations in practice (Vreugdenhil et al. 2024). By analysing stakeholder readiness of the groyne innovation process between 2020 and 2024, we identify adoption barriers, and map innovation progress over time and across organisational roles.

The following research questions are central in this paper:

- Which SRL dimensions constrained the adoption of flexible groynes in the period following the pilot?
- How did stakeholder readiness scores evolve across organisations between 2020 and 2024 to adopt flexible groynes?
- What added value does the SRL framework provide beyond technical pilot evaluations for understanding and supporting innovation adoption in river management?

By answering these questions, the paper makes two key contributions: (1) it operationalises stakeholder and institutional readiness in a multi-actor infrastructure context, and (2) demonstrates how SRL supports decision-making for scaling river innovations beyond pilots.

Materials and methods

Methods for innovation assessment

To analyse the institutional and stakeholder conditions shaping the adoption of flexible groynes, this study employs a qualitative longitudinal case study design combined with a structured stakeholder readiness assessment. The analytical focus is not on technological performance, which was assessed through existing hydraulic and ecological pilot monitoring, but on examining how organisational, financial, and regulatory readiness evolved across actors over time.

The Stakeholder Readiness Level (SRL) framework was therefore adopted as the primary analytical lens to capture these multi-actor and temporal dynamics. The SRL tool was applied at multiple moments following pilot implementation, enabling systematic comparison of stakeholder perceptions across time and participating organisations. This longitudinal application supports analysis of readiness trajectories rather than single-point assessments, which is particularly relevant for public river infrastructure innovations embedded in evolving governance and procurement contexts.

Table 1. Overview of selected innovation assessment frameworks relevant to river management, including core purpose, application areas, strengths, and limitations.

Framework	Core purpose	Main use areas	Strengths	Key limitations
Technology Readiness Level (TRL) (ESA 2009, Bates and Clausen 2020)	Measures technological maturity across 9 levels.	Medicine, industry, nature-based solutions.	Clear and widely recognised; tracks technical progress.	Neglects societal and institutional factors and perceptions (Olechowski et al. 2015); assumes fixed contexts.
Institutional Readiness (IR) analysis (Van Cauwenbergh et al. 2022)	Maps and classifies uncertainties in governance and organisational contexts; develops adaptive strategies.	Nature-based solutions, regenerative medicine.	Addresses institutional barriers; participatory, process-focused.	Limited insights on funding/ financing; categories need further unpacking.
MOTA framework (Sadik et al. 2022)	Assesses stakeholders' motivation, ability, and triggers for action.	Participatory water management, flood risk measures.	Captures behavioural drivers; unpacks stakeholder diversity.	Concepts can be subjective/ abstract (e.g. lacking information on funding, financing); lacks structured longitudinal use
Social Readiness Framework (Bellamy 2019)	Evaluates societal acceptance via trust, knowledge, scope, and impact dimensions.	Climate adaptation, technology acceptance, policy evaluation, risk perception	Anticipates societal acceptance/ resistance; integrates multiple theories.	Potential oversimplification of sociopolitical dynamics; limited empirical validation.
Societal Readiness Thinking Tool (Bernstein et al. 2022)	Uses guiding questions across project stages to reflect on values, ethics, and inclusivity (RRI framework).	Diverse: Research, innovation projects, policymaking.	Encourages reflexivity; links to Responsible Research & Innovation.	Complex navigation; mainly academic; needs facilitation.
Transformational Change Scorecard (Bickle et al. 2024)	Self-assessment roadmap for regional resilience journeys.	Climate adaptation, urban resilience, ecosystem restoration.	Encourages dialogue; tracks progress iteratively.	Subjective scoring; facilitation-intensive; participant fatigue possible.
Protective Action Decision Model (PADM) (Terpstra and Lindell 2013)	Explains how people decide to take protective actions in disaster contexts.	Flood risk management, disaster preparedness, public health.	Clarifies drivers of protective behaviour; supports risk communication.	Relies on cross-sectional designs; limited predictive capacity for resource factors.

The SRL tool

The SRL tool (www.srl-tool.nl), developed by Rijkswaterstaat and Deltares, evaluates organisational and contextual readiness for implementing and scaling innovations across five dimensions: Value (perceived benefits for users and society), Commitment & Support (internal enthusiasm, resistance), Costs (investment and implementation expenses), Feasibility (procedural feasibility, i.e. fit with systems and workflows, institutional norms, regulations), and Risks (awareness and mitigation of uncertainties). These dimensions reflect the core factors repeatedly identified in innovation literature as determinants of adoption. Value and Risks link to insights from technology acceptance and behavioural frameworks (e.g. Terpstra and Lindell 2013, Bellamy 2019); Commitment & Support reflects organisational commitment and social alignment highlighted in MOTA (Sadik et al. 2022); Feasibility corresponds to institutional and regulatory fit described in Institutional Readiness analysis (Van Cauwenbergh et al. 2022); and Costs capture the financial feasibility concerns that TRL and related frameworks typically neglect. By bringing these elements together in a stakeholder-centred format, the SRL tool synthesises the adoption factors that other approaches treat separately. Results are visualised in a colour-coded matrix, highlighting bottlenecks and decision points. An example of these matrices is presented in Figure 2. The tool is designed for repeated use across the innovation lifecycle, enabling longitudinal tracking of readiness.

Positioning SRL within innovation readiness assessment literature

To situate the SRL framework within the broader innovation assessment literature, we draw on and compare it with existing innovation assessment approaches. Table 1 summarises selected innovation assessment frameworks relevant to this study, while Supplementary Table S1 provides a more detailed comparison of these approaches and their characteristics. The Technology Readiness Level (TRL) framework (ESA 2009, Olechowski et al. 2015, Bates and Clausen 2020) assesses technological maturity across nine stages, but it largely neglects societal, organisational, and institutional embedding. Institutional Readiness (IR) analysis (Van Cauwenbergh et al. 2022) identifies governance uncertainties and organisational conditions for innovation uptake, while the Motivation and Ability (MOTA) framework (Sadik et al. 2022) explains behavioural readiness through stakeholder motivation, capacity, and triggers for action. Social readiness frameworks (Bellamy 2019) assess societal acceptance and resistance, and reflexive tools such as the Societal Readiness Thinking Tool (Bernstein et al. 2022) and the Transformational Change Scorecard (Bickle et al. 2024) facilitate iterative learning in collaborative innovation processes.

While these approaches offer valuable insights, they provide limited support for analysing multi-actor, infrastructure-based innovations such as river measures. Common gaps, including insufficient attention to financial and organisational adoption factors, weak integration of diverse stakeholder perspectives, and limited longitudinal assessment, underscore the need for a tool tailored to the social and institutional dynamics of river management.

Case study: the learning spaces

This research was conducted within the Dutch Learning Spaces programme, a collaborative environment embedded in 5–7 year river maintenance contracts tendered by Rijkswaterstaat, the Ministry of Infrastructure and Water's operational authority. The Learning Spaces act as living labs by bringing government, market, and research actors together to co-design and test innovations in river stretches (Schuurman and De Marez 2015, Vreugdenhil et al. 2024). This institutional coupling provides experimental space under real conditions, allowing assessment of technical feasibility, regulatory fit, and stakeholder alignment. Unlike traditional pilot setups, Learning Spaces are defined by innovation needs rather than predetermined locations, and their iterative, contract-embedded structure ensures continued collaboration, data collection, and decision cycles over multiple years. These characteristics, stable multi-year partnerships, shared risk governance, and direct links to maintenance procurement, create a supportive environment for infrastructure innovation in Dutch river management. As a result, Learning Spaces offer not only a realistic testbed for novel measures but also provide a suitable setting for applying the SRL tool, which relies on repeated engagement and cross-actor reflection.

The innovation cycle in a Learning Space comprises five phases: (1) Problem Definition, identifying challenges such as sediment control, climate adaptation, and biodiversity; (2) Ideation and Pitching, where stakeholders propose and assess innovations; (3) Design and Planning, turning concepts into action plans with roles, funding, and monitoring; (4) Piloting, real-world testing with interdisciplinary feedback; and (5) Evaluation and Scaling, assessing technical and institutional outcomes, as well as stakeholder readiness.

This process ensures innovations are both technically sound and institutionally embedded. Integrating SRL into evaluation strengthens the transition from pilots to systemic use. Learning Spaces have tested diverse measures, including bubble barriers for plastic

collection, aquatic drones, wooden screens for erosion control, and herded sheep for vegetation management. This paper focuses on Xstream blocks for flexible groynes (Buschman et al. 2024).

Pilot flexible groynes

Within the setting of the Learning Spaces, we examine the pilot of flexible groynes in the IJssel River. Traditional groynes have long played a crucial role in Dutch river management by guiding water flow and sediment transport, but they come with drawbacks, including ecological disruption and high maintenance demands. In contrast, flexible groynes, constructed from modular, porous Xstream blocks, can offer a more adaptive and ecologically sensitive solution (Figure 1, Buschman et al. 2024). To evaluate this innovation, a pilot was conducted in the IJssel River involving a governmental body, a research institute and several market parties (designer, developer, contractor). Following two years of implementation and monitoring, the SRL framework was used to determine whether participating stakeholders were prepared to support broader adoption. The pilot aimed to assess the technical, ecological, and operational feasibility of flexible groynes. The case was selected because pilot monitoring confirmed technical and ecological feasibility, yet large-scale adoption did not occur, making it suitable for analysing adoption barriers beyond technical performance.

Application of the SRL tool to the flexible groynes pilot

The SRL framework was applied after the pilot to assess stakeholder readiness and to examine the tool's utility in a multi-actor river management innovation context. The assessment served three aims: (1) evaluating readiness for broader adoption, (2) identifying institutional and financial barriers, and (3) experimenting with different application methods.

Data were collected at three moments (2020, 2023, and 2024), following the pilot's initial implementation in 2019 and subsequent monitoring phases in 2020 and 2023. Data collection consisted of structured process interviews with key representatives from each participating organisation (45–60 min per interview, with at least one representative per organisation), followed by a facilitated group session to jointly reflect on the preliminary SRL outcomes. In 2023 and 2024, additional group sessions were organised using real-time online polling with the six key partners:

- One government agency (potential adopter and decision-maker)
- One research institute (technical and ecological assessor)
- Four market actors (designer, contractor, development partner)

Responses were collected using a tailored SRL questionnaire based on the tool (see Supplementary Appendix S1), structured around the five SRL dimensions, and subsequently compiled into visual readiness matrices. The questionnaire operationalises the SRL dimensions through concrete items.

- Value: e.g. 'Does the innovation provide significant benefits for your organisation?' and 'Are societal benefits clearly demonstrated?'
- Commitment & Support: e.g. 'Is there internal support for adopting the innovation?' and 'Are key individuals or departments resistant?'

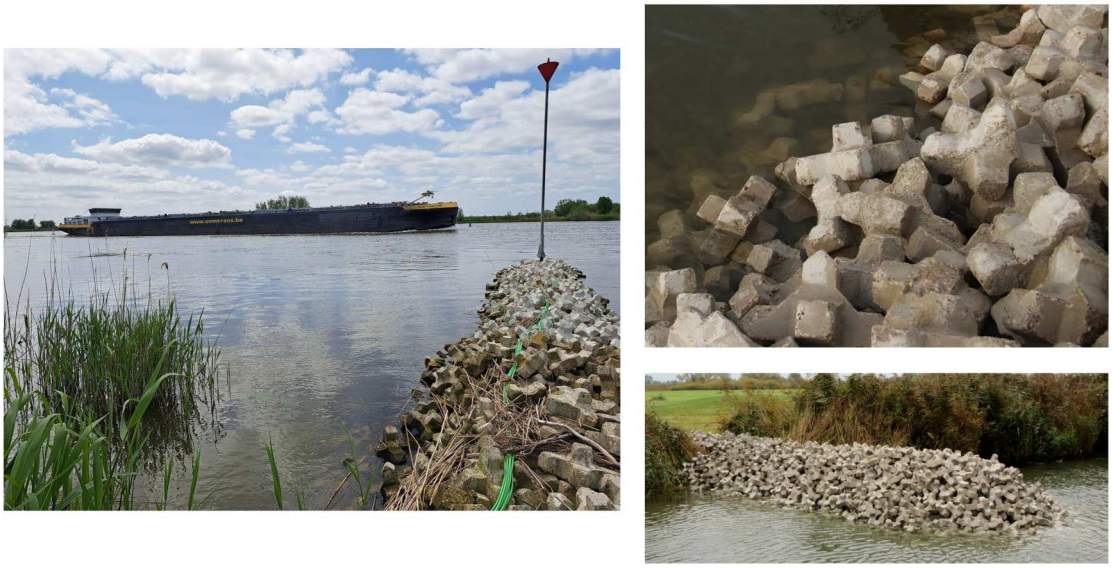


Figure 1. Flexible groynes in the river IJssel (adopted from Buschman et al. 2024).

- Costs: e.g. 'Are development, acquisition, and maintenance costs sufficiently known?' and 'Is a viable business model in place for involved parties?'
- Feasibility: e.g. 'Does the innovation fit existing regulations, procurement strategies, and work processes?'
- Risks: e.g. 'How confident are you in the innovation's reliability, safety, and environmental impact?'

Respondents scored each item on a qualitative scale (see Supplementary Appendix S1), supplemented by open-ended explanations to contextualise their assessments. For each assessment moment, at least one representative per participating organisation completed the questionnaire. Where multiple representatives from the same organisation participated, item-level responses were compared and discussed in a facilitated setting to arrive at a single consolidated organisational score per item.

For synthesis and visualisation, scores were aggregated per SRL dimension based on the presence and prevalence of concerns across organisations, rather than through numerical averaging. Colour categories therefore indicate whether concerns were absent, potential, or clear, and whether they were raised by one or multiple organisations (Figure 2). Responses marked as 'not applicable' or 'unknown' were treated as missing values for visual aggregation and addressed qualitatively during the reflection sessions to avoid imposing unwarranted numerical precision. This approach enabled direct comparison across SRL dimensions, stakeholder groups, and assessment years, supporting longitudinal analysis of readiness trajectories. The disaggregated stakeholder scores for 2020, 2023, and 2024 are provided in Supplementary Tables S2-S4.

Results: SRL analysis flexible groynes

Between 2020 and 2024, the SRL assessments reveal a gradual but uneven progression in readiness across actors and dimensions (Figure 2; Supplementary Tables S2-S4). Overall, the results indicate increasing convergence on Value and Feasibility, while Costs, Commitment & Support, and ownership-related issues persisted longer and evolved unevenly across stakeholder groups.

2020: Emerging perceived value, low readiness in costs and risks

As shown in Figure 2 (2020 panel) and Supplementary Table S2, flexible groynes were perceived as promising, but institutionally immature. The Value dimension is characterised by a combination of yellow, light orange, and orange indicators, indicating partial alignment but also uncertainty: While organisational value was generally considered to be in order, societal value and value for external stakeholders were associated with potential concerns. Feasibility was not considered problematic, although one stakeholder questioned the sales strategy, indicating early uncertainty about market positioning rather than technical integration. More significant concerns emerged in the Costs and Risks dimensions, particularly regarding transition costs and reliability, which were consistently rated as major concerns across multiple stakeholders (Supplementary Table S2). These included investment readiness, the absence of a clear business model, and uncertainties about long-term reliability and environmental impact. The Commitment & Support dimension also shows multiple potential concerns (Figure 2), particularly related to investment willingness, internal resistance, and the influence of other stakeholders. The Risks dimension shows the strongest concerns overall, with multiple red indicators for reliability, material sustainability, and availability, indicating fundamental uncertainty about the performance of the innovation.

2023: Reduced feasibility and risks concerns, persistent barriers in commitment & support and costs

By 2023, SRL scores show improvements in perceptions of Feasibility, Value and Risks (Figure 2, 2023 panel; Supplementary Table S3). Compared to 2020, the number of red and orange indicators decreased markedly across most dimensions. Two additional stakeholders joined the assessment, reflecting a broader innovation network and increased market interest.

Consensus on societal value was strong, although the translation of this value into specific organisational benefits remained contested for some actors. Feasibility was no longer perceived as an obstacle, indicated by the absence of red indicators in the Feasibility dimension, signalling increased confidence in integration into existing practices. Residual issues persisted in the Commitment & Support dimension, particularly related to internal resistance (red indicator) and limited willingness to invest (light red), as well as in the Costs dimension, especially regarding development and scaling costs.

In the Risks dimension, most concerns shifted to yellow, with only isolated issues remaining, mainly related to safety. Stakeholder-specific analysis highlights differentiated readiness trajectories: a market actor that previously reported multiple concerns no longer identified major bottlenecks, while a newly involved commercial entrant raised minor uncertainties about cost transparency and potential applications. The contractor resolved earlier concerns related to reliability and environmental impact, and the government addressed strategic and financial

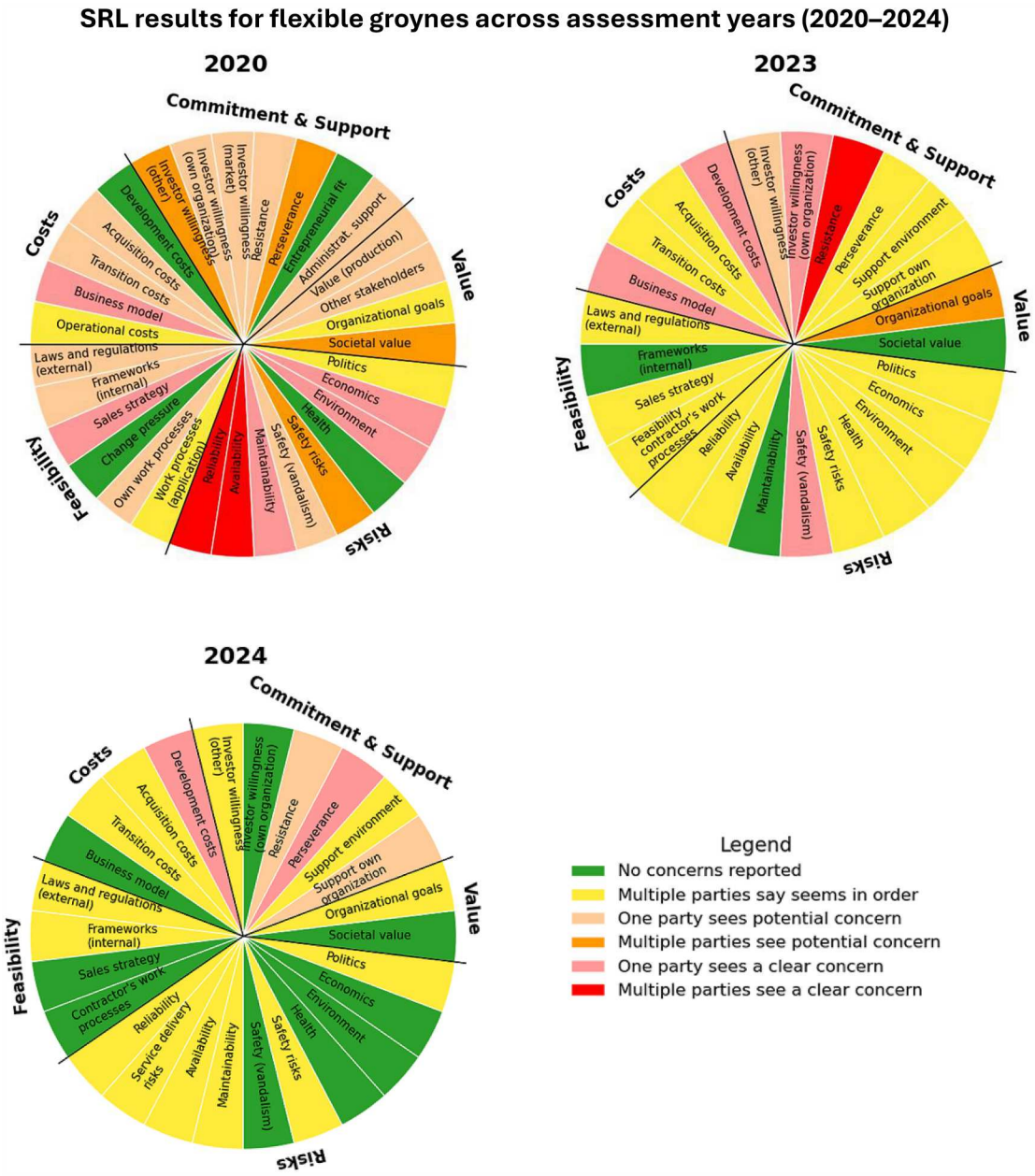


Figure 2. Stakeholder Readiness Level (SRL) assessment results for the flexible groyne innovation in 2020, 2023, and 2024. Each wheel visualises stakeholder perceptions across five dimensions: Value, Commitment & Support, Costs, Feasibility, and Risks. Colours represent aggregated stakeholder concerns: green indicates no concerns reported by any organisation; yellow indicates issues largely considered in order; light orange indicates a potential concern raised by one organisation; orange indicates potential concerns raised by multiple organisations; light red indicates a clear concern raised by one organisation; and red indicates clear concerns raised by multiple organisations.

issues. In contrast, the research institute remained the least ready actor, continuing to register notable reservations in Commitment & Support, Costs, and Risks.

2024: Convergence among adopters, residual bottlenecks

In 2024, SRL outputs demonstrate convergence toward high readiness among government and market actors while persistent concerns within the research institute continued (Figure 2, 2024 panel; Supplementary Table S4). The final assessment shows readiness matrices dominated by green and yellow indicators across most dimensions.

All stakeholders endorsed the strategic and societal value of the innovation, and feasibility-related concerns had disappeared entirely. Remaining risk-related issues were limited and focused primarily on long-term maintainability and potential ecological impacts, voiced mainly by the research institute. Cost-related concerns diminished substantially: while the new commercial entrant still lacked clarity on development costs (light red indicator), transition and acquisition costs, as well as the overall business model, were generally considered resolved by other actors.

Both the contractor and the government reported no remaining concerns across any SRL dimension. The research institute, however, continued to register potential concerns, particularly in Commitment & Support, Costs, and Risks (Figure 2). These reflected unresolved internal alignment issues, investment uncertainty, and the absence of a designated lead partner for implementation (Supplementary Table S4).

Cross-year patterns and primary bottlenecks (2020–2024)

Across the three assessments, perceived value increased over time and feasibility improved steadily as pilot monitoring confirmed hydraulic and ecological performance and the government agency clarified how flexible groynes could be embedded within existing maintenance procedures.

The most pronounced improvements occurred in the Costs and Risks dimensions, which shifted from widespread concerns in 2020 to largely resolved or minor issues by 2024. These changes were supported by follow-up ecological monitoring, more detailed cost estimates provided by contractors, and refinements to installation and maintenance procedures, all of which reduced uncertainty.

In contrast, the Commitment & Support dimension showed the most uneven trajectory (Figure 2). While contractors and government actors reported increasing readiness as financing options and procurement pathways became clearer, the research institute continued to experience internal misalignment and investment hesitation, partly due to the lack of a designated lead partner for further development.

Despite overall progress, key bottlenecks remain, particularly uncertainties related to development costs and scaling, the need for regulatory adjustments to formally permit flexible groynes, and lingering ecological and organisational concerns within the research institute. These remaining bottlenecks indicate that barriers do not simply decline over time, but may also shift, persist, or become more visible as the innovation moves closer to scaling. Together, these factors help to explain why large-scale implementation has not yet occurred.

Discussion

SRL as a reflective diagnostic tool

The Stakeholder Readiness Level framework proved valuable as a reflective and diagnostic tool following the flexible groyne pilot. While technical evaluations confirmed hydraulic and ecological feasibility, residual technical questions remained, for example relating to CO_2 performance, long-term ecological effects, possibilities to reduce production costs, and opportunities to diversify applications. SRL assessment made these remaining uncertainties explicit by revealing how different stakeholders interpreted these issues as either residual risks or acceptable uncertainties. This is visible in Figure 2 through the persistence of orange and red indicators in specific dimensions. In doing so, the tool revealed hesitations, misalignments, and institutional barriers that would otherwise remain hidden. Stakeholders generally recognised these insights as a realistic reflection of their own concerns and used the SRL outcomes as a basis for structured discussion rather than as a judgement. The visualisation helped to legitimise previously implicit doubts and increased motivation to clarify responsibilities, identify follow-up actions, or distinguish between technical questions and organisational constraints. Importantly, the analysis also showed that several social and organisational concerns were rooted in unresolved technical uncertainties, demonstrating how technical and institutional factors are closely intertwined in innovation adoption. This finding underscores that adoption barriers cannot be cleanly separated into 'technical' versus 'social' domains, but instead co-evolve over time, as some barriers are resolved through monitoring, cost clarification, or procedural learning, while others become salient only when the innovation approaches wider application and questions of ownership, financing, regulation, and organisational responsibility become more concrete.

By structuring dialogue across five readiness dimensions (Value, Commitment & Support, Costs, Feasibility, and Risks) the tool identified which aspects required further work before scaling and provided a shared space for cross-organisational reflection. As illustrated in Figure 2, improvements in Feasibility and Risks did not automatically translate into higher Commitment & Support or Costs readiness. While SRL successfully highlighted adoption bottlenecks, it is important to note that the tool does not in itself resolve structural barriers such as financing gaps or regulatory misfits. Rather, it provides a platform to surface and structure these issues for dialogue.

Uneven readiness and diversity of stakeholder perspectives

Readiness did not evolve uniformly across actors and over time. Figure 2 shows that contractors and government actors converged toward high readiness, while the research institute retained concerns. Contractors' willingness to adopt improved once financing options became clearer, while the research institute's alignment lagged despite technical confidence. This uneven progress mirrors broader patterns in innovation adoption, where motivation and ability, shaped by organisational resources and perceptions, condition readiness.

SRL made the diversity of perspectives among actors visible (Figure 2). The research institute remained cautious due to ecological uncertainties, whereas contractors prioritised financial clarity and implementation conditions. These contrasting priorities reflect different organisational roles and responsibilities within river management innovation processes. Such divergences echo earlier findings that innovation adoption in Dutch water management depends not only on technical evidence but also on cultural perspectives shaping risks and value (cf. Offermans et al. 2011, Offermans and Cörvers 2012). This highlights the continued dominance of hierarchical, safety-oriented perspectives that can constrain more experimental, stakeholder-driven solutions.

Persistence of financial and regulatory barriers

Beyond differences in stakeholder perspectives, the analysis also highlights structural barriers that cut across actor groups. In particular, the absence of a viable business model emerged as a major barrier. This is reflected in persistent concerns in the Costs dimension in Figure 2, particularly in earlier assessment years. Public innovation subsidies in the Netherlands, such as national co-funding schemes that support experimental pilots, enabled the flexible groyne trials, but large-scale adoption requires structural financing mechanisms. Without them, market actors remain cautious. This finding reflects Grotenbreg and van Buuren's (2018) observation that pilots often stall due to funding gaps and institutional inertia.

Regulatory procedures also posed obstacles, as current permitting standards are designed for traditional groynes. This is reflected in earlier feasibility concerns that diminish over time in Figure 2. In this case, regulatory misfit concerned both formal approval criteria and informal norms regarding acceptable uncertainty in river engineering practice. Flexible groynes therefore require regulatory adjustments that better reflect their hydraulic performance and ecological benefits, as well as procedural flexibility during early adoption stages.

Ecological concerns are closely linked to the spatial and temporal variability of river systems and their inherently non-discrete nature. The performance of interventions such as flexible groynes is context-dependent, meaning that outcomes observed in pilot locations cannot be directly generalised to other river stretches. This limits the transferability of evidence and contributes to regulatory caution, as permitting frameworks rely on predictable and standardised performance. As a result, uncertainty about broader system responses can hinder large-scale implementation and slow regulatory adaptation (e.g. Palmer et al. 2005 Bellamy 2019, Van Cauwenbergh et al. 2022,).

Positioning the SRL framework among reflexive innovation tools

SRL belongs to a wider family of reflexive innovation assessment approaches, including the Societal Readiness Thinking Tool (Bernstein et al. 2022) and the Transformational Change Scorecard (Bickle et al. 2024). Like these, it stimulates reflection and dialogue, but its structured readiness matrix proved particularly effective in visualising stakeholder-specific bottlenecks and facilitating co-interpretation in multi-actor settings. While several frameworks exist to assess innovation maturity and adoption potential, the SRL framework offers a distinct contribution. Early readiness scores for flexible groynes remained low despite positive technical results, reinforcing critiques of the Technology Readiness Level (TRL) framework, which largely neglects institutional and societal dimensions (May et al. 2011, Hauck et al. 2019). The results (Figure 2) show that readiness remained uneven despite positive technical outcomes, confirming that technological maturity alone does not ensure adoption. As Webster and Gardner (2019) and Van Cauwenbergh et al. (2022) argue, regulatory alignment, organisational capacity, and cross-sectoral participation are critical conditions for mainstreaming innovations. SRL operationalises these conditions through a longitudinal, actor-specific assessment, making readiness gaps visible over time rather than inferred post hoc. This reinforces the insight that technological maturity alone cannot drive implementation: moving from a proven prototype to widespread use requires sufficient alignment across organisational support, financing, procedural integration, and risk acceptance among key actors.

Unlike TRL, which focuses primarily on technological maturity, or MOTA, which foregrounds behavioural drivers, SRL assessment integrates five adoption-relevant dimensions (Value, Commitment & Support, Costs, Feasibility, and Risks) within a single stakeholder-centred framework. Compared to Institutional Readiness analysis (Van Cauwenbergh et al. 2022), SRL places greater emphasis on practical adoption factors such as financing and procedural integration, which proved decisive in the flexible groyne case. Moreover, its longitudinal application allows readiness trajectories to be tracked, a feature largely absent in other approaches. By combining these elements in a structured, visual format, the SRL tool not only diagnoses adoption barriers but also actively supports collaborative decision-making in infrastructure innovation contexts. As with other reflexive innovation tools, critics of reflexive tools warn that their outputs can remain descriptive unless

embedded in decision-making processes (Hauck et al. 2019, Van Cauwenbergh et al. 2022). Our case confirms this tension: SRL assessments effectively diagnosed adoption bottlenecks but did not itself resolve financing or regulatory barriers. Its value thus lies in structuring and legitimising dialogue, rather than prescribing solutions.

To illustrate how SRL complements the TRL framework, Figure 3 positions the Stakeholder Readiness Level tool alongside the stages of the TRL framework and stakeholder readiness trajectory (Innovation Fund Denmark 2019). While TRL charts technological progress from basic research to operational deployment, SRL describes the extent to which stakeholders, organisations, governance arrangements, and financing structures are prepared to adopt and embed an innovation in practice. The figure distinguishes between SRL levels (describing readiness states) and the SRL tool (supporting dialogue and diagnosis). The increasing size of the SRL diagrams indicates that the importance of structured stakeholder dialogue grows as technologies approach implementation. In early TRL stages (1-3), the SRL tool helps articulate expected value and identify initial stakeholder support and risks; in mid-development (TRL 4-6), it highlights feasibility requirements, cost structures, and role clarity. In later TRL stages (TRL 7-9), when technologies are technically proven but often struggle to move beyond pilots, SRL assessment becomes particularly critical for identifying institutional, financial, and organisational barriers to adoption.

Broader lessons for river management

Three broader lessons emerge. First, early engagement is essential to surface misalignments and address barriers before scaling. The flexible groynes evolved through several stages, from laboratory studies, to a first controlled field test, and subsequently to a full-scale pilot in the IJssel River (Figure 1), and at each stage, new concerns and opportunities surfaced. These involved ecological functioning, durability, procurement, and long-term ownership. Addressing such issues early prevents technical progress from outpacing institutional readiness. Second, embedding SRL in iterative, collaborative environments such as Learning Spaces helps bridge the gap between technical feasibility and institutional adoption (Hall and Persson 2018, Lenaerts et al. 2022). These settings enabled government agencies, researchers, and market actors to jointly interpret monitoring results, discuss operational constraints, and refine expectations regarding implementation. SRL assessments supported this process by identifying where readiness improved (e.g. confidence in hydraulic performance) and where it remained limited (e.g. business models, regulatory fit). Third, linking readiness assessments to contractual arrangements, such as the Dutch Ministry's

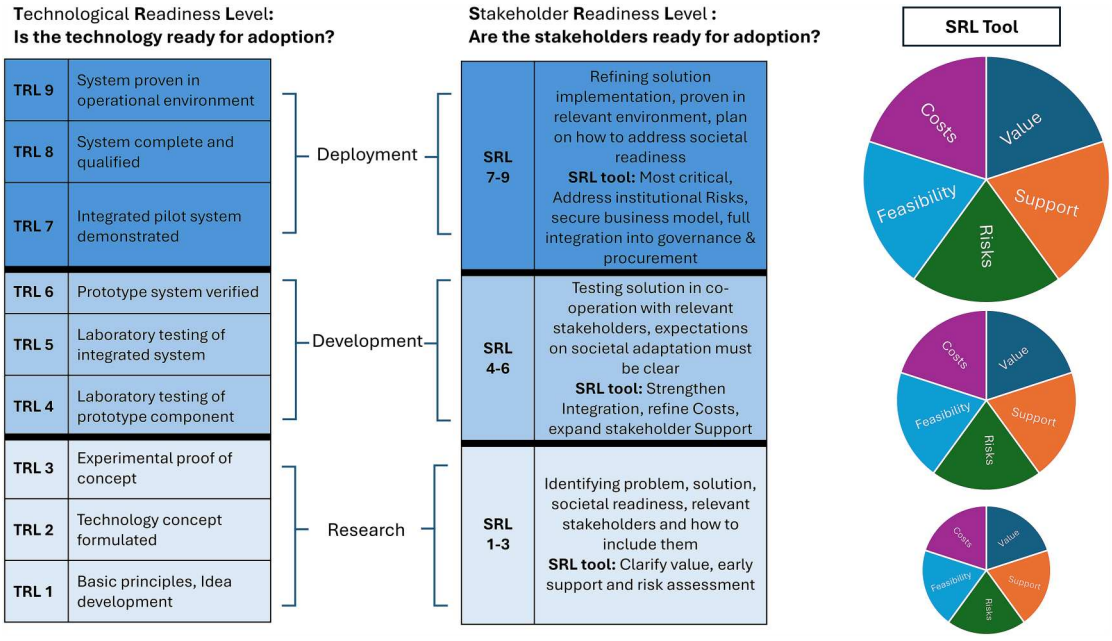


Figure 3. Conceptual relationship between Technology Readiness Levels (TRL) and Stakeholder Readiness Levels (SRL), adapted from Innovation Fund Denmark (2019). TRL describes technological maturation from basic research (TRL 1–3), through development and pilot testing (TRL 4–6), to operational deployment (TRL 7–9). SRL levels characterise the degree to which stakeholders and institutional contexts are ready to adopt the technology. The increasing size of the SRL-tool diagrams illustrates the growing importance of structured stakeholder dialogue as innovations move closer to implementation. SRL evaluates five dimensions: Value (societal and organisational benefits), Support (internal and external commitment), Costs (business model and investment readiness), Feasibility (alignment with laws, procurement, and work processes), and Risks (technical, ecological, social, political, and safety concerns). Together, the figure illustrates that advancing technological readiness requires parallel strengthening of stakeholder readiness across these dimensions.

integration of Learning Spaces into maintenance tenders, provides institutional leverage to accelerate upscaling. In this case, the structured innovation space enabled contractors and authorities to test flexible groynes under real conditions, evaluate risks, and build procedural familiarity.

Looking ahead, the flexible groyne concept shows promising potential for wider application. Interviews with stakeholders indicate opportunities for deployment in damaged groynes requiring repair or replacement. The modularity of the system also makes it relevant for international river systems facing similar sediment, navigation, and ecological challenges. However, realising this potential requires resolving remaining readiness issues, particularly clarifying financing models, refining regulatory approval pathways, and designating long-term ownership, underscoring the continued importance of SRL as a tool for navigating the transition from pilot to practice.

Limitations and practical considerations

As with other readiness tools, the SRL tool requires contextual tailoring. Not all questions are relevant in every case, and interpretations varied across participants, underscoring the need for careful facilitation. The use of both structured process interviews and real-time polling helped reveal differences in how readiness levels were understood, while also supporting collective reflection. In its current form, the tool therefore requires support or guidance from a facilitator or researcher, particularly to ensure consistent interpretation of questions and to translate results into follow-up actions. This points to the need for alternative formats that can be used in a more independent and dynamic way during stakeholder workshops, for example through poster-based exercises in which participants indicate hesitation points and jointly discuss readiness barriers. Nonetheless, the tool's flexible design allows adaptation to diverse contexts.

Furthermore, the findings should be interpreted with caution. First, the analysis draws on a relatively small group of stakeholders within the Dutch water governance context, which may limit the generalisability of results to other institutional settings. The composition of participants in Learning Spaces may influence the diversity of perspectives represented. As participation is typically based on existing project partners and institutional roles, certain stakeholder groups may be underrepresented. This can affect how problems are framed and discussed, potentially limiting the range of perspectives considered in the innovation process. Second, SRL assessments rely on self-reported stakeholder perceptions, which are shaped by organisational cultures, power relations, and facilitation processes. While this is consistent with the tool's reflexive intent, it limits comparability and requires careful facilitation to ensure balanced interpretation. Third, the analysis is based on a single innovation case within the Dutch river governance context. Application of SRL across multiple cases and institutional settings would be needed to assess its broader applicability and transferability.

Conclusion

The flexible groyne case demonstrates that successful innovation in river management requires more than technical feasibility; it depends on the readiness of stakeholders to adopt, finance, and embed new practices within established institutional settings. While pilot monitoring confirmed the hydraulic and ecological benefits of flexible groynes, adoption trajectories were shaped by divergent perspectives, financial uncertainties, and regulatory constraints.

The Stakeholder Readiness Level (SRL) framework proved effective in making these dynamics explicit. As demonstrated in Figure 2, the tool captures how readiness evolved across dimensions and stakeholders. By structuring reflection across Value, Commitment & Support, Costs, Feasibility, and Risks, SRL identified adoption bottlenecks that conventional technical evaluations overlook. Its iterative application captured how readiness evolved unevenly and non-linearly among actors, offering a basis for targeted interventions and facilitating dialogue across organisational boundaries.

For river basin management, three implications follow. First, readiness assessments should be embedded early and repeatedly within innovation processes to anticipate and address institutional barriers. Second, coupling SRL with collaborative structures such as Learning Spaces enhances its diagnostic power, aligning technical, ecological, and stakeholder dimensions. Third, linking readiness evaluation to contractual and regulatory arrangements can provide the leverage needed to move from experimentation to large-scale implementation.

In sum, SRL complements existing frameworks such as TRL by operationalising the institutional and social dimensions of innovation adoption. The longitudinal patterns observed in Figure 2 illustrate how stakeholder readiness evolves alongside technological maturity. Its application to the flexible groyne case illustrates how readiness-oriented assessment can support decision-making in river management by clarifying when innovations are not yet failing technically, but are not yet ready institutionally. As such, SRL offers a practical decision-support tool for authorities and market actors seeking to accelerate the transition of river innovations from pilot projects to systemic practice.

Acknowledgements

The authors thank the participating stakeholders from government, research, and market organisations for their sustained engagement in the SRL assessments and Learning Spaces. The authors also acknowledge the Learning Spaces programme for providing a collaborative environment for experimentation and reflection. The authors used AI-assisted language tools to assist with language editing. All scientific content, analysis, interpretation, and conclusions are the sole responsibility of the authors.

Author contributions

CRediT: **Julia Bleser:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft; **Heleen Vreugdenhil:** Conceptualization, Methodology, Project administration, Supervision, Visualization, Writing – review & editing; **Shahnoor Hasan:** Formal analysis, Investigation, Writing – original draft, Writing – review & editing; **Nick Leung:** Writing – review & editing; **Sonja Karstens:** Writing – review & editing.

Disclosure statement

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. All SRL assessments were conducted through facilitated, multi-actor sessions, and findings reflect consolidated stakeholder perspectives rather than organisational positions..

Funding

This research was funded through SITO Programme Subsidy funding from the Ministry of Infrastructure and Water Management and the Rijkswaterstaat Corporate Innovation Program (CIP), and was supported by Deltares and the Multi-Actor Systems section of the Faculty of Technology, Policy and Management at Delft University of Technology.

ORCID

Julia Bleser http://orcid.org/0009-0007-5181-912X

References

Bates, C.A., and Clausen, C, 2020. Engineering readiness: how the TRL figure of merit coordinates technology development. *Engineering Studies*, 12 (1), 9–38. doi:10.1080/19378629.2020.1728282.

Bellamy, R, 2019. Social readiness of adaptation technologies. *Wiley Interdisciplinary Reviews: Climate Change*, 10 (6), e623. doi:10.1002/wcc.623.

Bernstein, M.J., et al., 2022. The societal readiness thinking tool: a practical resource for maturing the societal readiness of research projects. *Science and Engineering Ethics*, 28, 3. doi:10.1007/s11948-021-00360-3.

Bickle, M., et al., 2024. *Guidance and scorecard readiness assessments of transformative change across regions (deliverable 7.1)*. Amsterdam: Climate KIC. Available at: https://edepot.wur.nl/684504.

Buschman, F.A., et al., 2024. *Evaluatie flexibele krib in relatie tot een traditionele krib: Analyse fase 2 van praktijkproef bij Kampen in de IJssel*. Delft: Deltares.

Chu, E.K., et al., 2025. Broadening diversity, equity, accessibility, and inclusion in the process and development of climate assessments. *Climatic Change*, 178 (4), 63. doi:10.1007/s10584-025-03873-z.

ESA (European Space Agency), 2009. *Technology readiness levels: handbook for space applications*. Noordwijk: ESTEC.

Grotenbreg, S., and van Buuren, A., 2018. Realizing innovative public waterworks: aligning administrative capacities in collaborative innovation processes. *Journal of Cleaner Production*, 171, S45–S55. doi:10.1016/j.jclepro.2016.08.128.

Hall, N., and Persson, Å, 2018. Global climate adaptation governance: why is it not legally binding? *European Journal of International Relations*, 24 (3), 540–566. doi:10.1177/1354066117725157.

Hauck, J., et al., 2019. Combining policy analyses, exploratory scenarios, and integrated modelling to assess land use policy options. *Environmental Science & Policy*, 94, 202–210. doi:10.1016/j.envsci.2018.12.009.

Innovation Fund Denmark, 2019. Societal Readiness Levels (SRL) defined according to Innovation Fund Denmark. Available at: https://innovationsfonden.dk/sites/default/files/2019-03/societal_readiness_levels_-_srl.pdf [Accessed 16 Jan 2026].

IPCC, 2013. *Climate change 2013: the physical science basis*. Cambridge: Cambridge University Press. doi:10.1017/CBO9781107415324

Jong, P., and van den Brink, M., 2017. Between tradition and innovation: developing Flood Risk Management Plans in the Netherlands. *Journal of Flood Risk Management*, 10 (2), 155–163. doi:10.1111/jfr3.12070.

Kovats, R.S., Valentini, R., Bouwer, L.M., Georgopoulou, E., Jacob, D., Martin, E., 2014. Europe. *In*: V.R. Barros, C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, eds. *Climate change 2014: impacts, adaptation, and vulnerability. part B: regional aspects*. Cambridge: Cambridge University Press, 1267–1326. Available at: http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap23_FINAL.pdf [Accessed 16 Jan 2026].

Lenaerts, K., Tagliapietra, S., and Wolff, G.B, 2022. How can the European union adapt to climate change? *Intereconomics: Review of European Economic Policy*, 57 (5), 314–321. doi:10.1007/s10272-022-1071-4.

May, C.R., et al., 2011. Evaluating complex interventions and health technologies using normalization process theory. *BMC Health Services Research*, 11, 245. doi:10.1186/1472-6963-11-245.

Offermans, A., and Cörvers, R, 2012. Learning from the past; changing perspectives on river management in The Netherlands. *Environmental Science & Policy*, 15 (1), 13–22. doi:10.1016/j.envsci.2011.10.003.

Offermans, A., Haasnoot, M., and Valkering, P, 2011. A method to explore social response for sustainable water management strategies under changing conditions. *Sustainable Development*, 19 (5), 312–324. doi:10.1002/sd.439.

Olechowski, A.L., Eppinger, S.D., and Joglekar, N, 2015. Technology readiness levels at 40: A study of state-of-the-art use, challenges, and opportunities. MIT Sloan Research Paper No. 5127-15, SSRN Electronic Journal [online]. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2588524 [Accessed 16 Jan 2026].

Palmer, M. A., et al., 2005. Standards for ecologically successful river restoration. *Journal of Applied Ecology*, 42 (2), 208–217. doi:10.1111/j.1365-2664.2005.01004.x.

Pielke, R.A., et al., 2007. Climate change 2007: lifting the taboo on adaptation. *Nature*, 445 (7128), 597–598. doi:10.1038/445597a.

Sadik, M.S., et al., 2022. Assessing the societal adoptability of participatory water management: an application of the motivation and ability (MOTA) framework. *Water Policy*, 24 (5), 729–746. doi:10.2166/wp.2021.255.

Schuurman, D., and De Marez, L., 2015. Living labs: a structured approach for implementing open and user innovation. *In* Proceedings of the 13th Annual Open and User Innovation Conference. Lisbon. Available at: http://hdl.handle.net/1854/LU-6888241.

Terpstra, T., and Lindell, M.K, 2013. 'Citizens' perceptions of flood hazard adjustments: an application of the protective action decision model'. *Environment and Behavior*, 45 (8), 993–1018. doi:10.1177/0013916512452427.

Van Buuren, A., Vreugdenhil, H., van Popering-Verkerk, J., Ellen, G.J., van der Leeuwen, C.W.G.J. and Breman, B., 2019. The pilot paradox. *In*: B. Turnheim, P. Kivimaa and F. Berkhout, eds. *Innovating climate governance*. Cambridge: Cambridge University Press, 148–165. doi:10.1017/9781108277679.011

Van Cauwenbergh, N., et al., 2022. Beyond TRL – understanding institutional readiness for implementation of nature-based solutions. *Environmental Science & Policy*, 127, 293–302. doi:10.1016/j.envsci.2021.09.021.

van den Brink, M.A., Termeer, C.J.A.M., and Meijerink, S., 2011. Are Dutch water safety institutions prepared for climate change? *Journal of Water and Climate Change*, 2 (4), 272–287. doi:10.2166/wcc.2011.044.

Vreugdenhil, H., et al., 2010. The influence of scale preferences on the design of a water innovation: a case in Dutch river management. *Environmental Management*, 46 (1), 29–43. doi:10.1007/s00267-010-9524-0.

Vreugdenhil, H., et al., 2024. Learning Spaces as Living Labs in Dutch River Management: Joint Effort to Improve River Management through Innovation. Conference paper, OpenLivingLab Days 2023, 21–23 September 2023, Barcelona. Zenodo [online]. Available at: https://zenodo.org/records/11210049 [Accessed 16 Jan 2026].

Webster, A., and Gardner, J, 2019. Aligning technology and institutional readiness: the adoption of innovation. *Technology Analysis & Strategic Management*, 31 (10), 1229–1241. doi:10.1080/09537325.2019.1601694.