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ABSTRACT

Adaptation pathways approaches support long-term planning under uncertainty. The use of adaptation pathways implies a systematic monitoring effort to inform future adaptation decisions. Such monitoring should feed into a long-term collaborative learning process between multiple actors at various levels. This raises questions about who should monitor what, when and for whom. We formulate an approach that helps to address these questions, developed around the conceptual core offered by adaptive policy pathways methods and their notion of signposts and triggers. This is embedded in a wider approach that revisits the critical assumptions in underlying basic policies, looks forward to future adaptation decisions, and incorporates reciprocity in the organization of monitoring and evaluation. The usefulness and practical feasibility of the approach is studied for a case of the Delta Programme in the Netherlands, which incorporated adaptation pathways in its planning approach called adaptive delta management. The case results suggest that our approach adds value to existing monitoring practices. They further show that different types of signposts exist. Technical signposts, in particular, need to be distinguished from political ones, and require different learning processes with different types of actors.

1. Introduction

Adaptation pathways has emerged in recent years as a planning approach to deal with climate change adaptation and societal transformation. Adaptation pathways stresses the notion that, at various points in time, different decisions are possible, whereby path-dependence links different decisions in a longer-term pathway (Haasnoot et al., 2013; Reeder and Ranger, 2010; Stafford Smith et al., 2011). Visually representing these policy decisions as a dynamic sequence of several smaller decisions over time enables decision-makers to overcome some of the barriers associated with making long-term climate adaptation decisions (Stafford Smith et al., 2011; cf. Wise et al., 2014). Pathways approaches and principles have been used to support for instance the Thames estuary flood risk management planning (Reeder and Ranger, 2010; Stafford Smith et al., 2011), the Dutch Delta Programme for water security and safety in the Netherlands (Haasnoot et al., 2013; Delta Programme, 2015), conservation planning for forests in Australia (Colloff et al., 2016), and a dialogue about adaptive capacity in Indonesia (Butler et al., 2016).

Pathways approaches imply an important role for monitoring and evaluation, to track progress in implementation and to inform timely sequential decision-making (e.g. Stafford Smith et al., 2011; Haasnoot et al., 2013; Butler et al., 2016). Adaptation pathways plans typically deal with uncertain dynamic settings and involve and affect multiple actors, which means that monitoring needs to feed into a process of collaborative learning and reflection (Kallis et al., 2009; Wise et al., 2014). In these settings, well-planned monitoring frameworks, with carefully devised indicators, can provide important support for collaborative learning, offering guidance for management and external communication (e.g. De Bruijn, 2007).

Despite the recognition of the importance of monitoring and evaluation in adaptation, to date few studies have focused on the monitoring process in relation to adaptation pathways approaches. The design of functional monitoring and evaluation arrangements is difficult, as is apparent from the debate on the gap between policy evaluations and their use for real world policy making (Weiss, 1999; Levine and Savedoff, 2006). Furthermore, pathways approaches are different from more conventional planning approaches, as they include different alternative adaptation options over time, which are triggered by pre-specified conditions. This forward-looking flexible character of adaptation pathways

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plans needs to be included in the monitoring and evaluation arrangements, meaning that those need to be different from the conventional policy and plan evaluation arrangements.

In this paper, we address the question of how to design monitoring and evaluation arrangements for adaptation pathways that can support collaborative learning for policy making. We do so by first reviewing the characteristics of adaptation pathways approaches and the challenges these pose for monitoring and evaluation. In response to these challenges, we formulate an approach to design monitoring arrangements for adaptation pathways. This approach is explored for its usefulness and practical feasibility in a case of adaptation pathway planning in the Delta Programme in the Netherlands. This results in a further discussion and sharpening of the approach, with which the paper concludes.

2. Challenges in the design of monitoring arrangements for adaptation pathways

2.1. A short introduction to adaptation pathways planning

Adaptation pathways provide an analytical framework that helps position short- and medium-term policy decisions within longer-term strategic ambitions. Typically, several long-term pathways are considered, each of which may support the realization of long-term ambitions under different conditions. Fig. 1 shows the adaptation pathways approach as used in Dynamic Adaptive Policy Pathways (Haasnoot et al., 2013). Several pathways are shown, starting at the left with the path that starts from the current situation, indicating current policy actions. After a certain time, current policy actions are expected to be no longer effective. An adaptation tipping point is reached, which necessitates a transfer to a new policy action. In a well-planned adaptation process, the decisions about the preferred new policy actions are taken before adaptation tipping points are reached. Adaptation signals will help to anticipate upcoming adaptation decisions. These adaptation signals are based on predefined variables, which are called signposts (Haasnoot et al., 2013; Walker et al., 2013). Signpost indicators help to see if the conditions that are critical to policy success are still being met, if the underlying analysis remains valid, and if policy implementation proceeds according to schedule. Triggers are the values associated with signpost variables that signal a need for reconsideration or adaptive action (Haasnoot et al., 2013; Walker et al., 2013). The time at which adaptation tipping points are reached is not yet known, but depends on the dynamics in future developments. Different future scenarios are used to provide an idea of the bandwidth of time within which adaptation decisions might be expected.

Adaptation pathways plans suggest policy actions for the short to medium term, within a longer-term pathway. These immediate policy actions are assembled in what is called a basic policy (Walker et al., 2013). In the pathways map shown in Fig. 1, this basic policy corresponds to the "Current situation", which provides the first path in an adaptation pathways plan. Monitoring may trigger a new decision, depicted as a decision node, which is to select and prepare for the appropriate 'transfer station' to a new policy action on the pathways map. Under different scenarios and for different time horizons, costs and benefits may be estimated for different sequences of policy actions.

As simple as these analytic principles sound, various complications emerge for monitoring.

2.2. The presumed implementation and effectiveness of adaptation pathways

The call for monitoring and evaluation of adaptation pathways stems first and foremost from the expectation that adaptation pathways are being implemented and that the developed plans help identify the variables that need to be monitored. However, Wise et al. (2014) suggest that adaptation plans are often not implemented and, if they are, it is only the smaller incremental measures within those plans. Van der Brugge and Roosjen (2015) explain how this might be due to the changes in institutional and socio-cultural structures required for the implementation of adaptation strategies. This implementation problem is not unique to adaptation pathways. For instance, Waldner (2009) showed that local government units do not necessarily implement their own spatially restrictive land use policies. Implementation would have to be done through the local development departments and especially when alternative sites for development were scarce, spatial restrictions were easily forgotten (Waldner, 2009). Earlier,

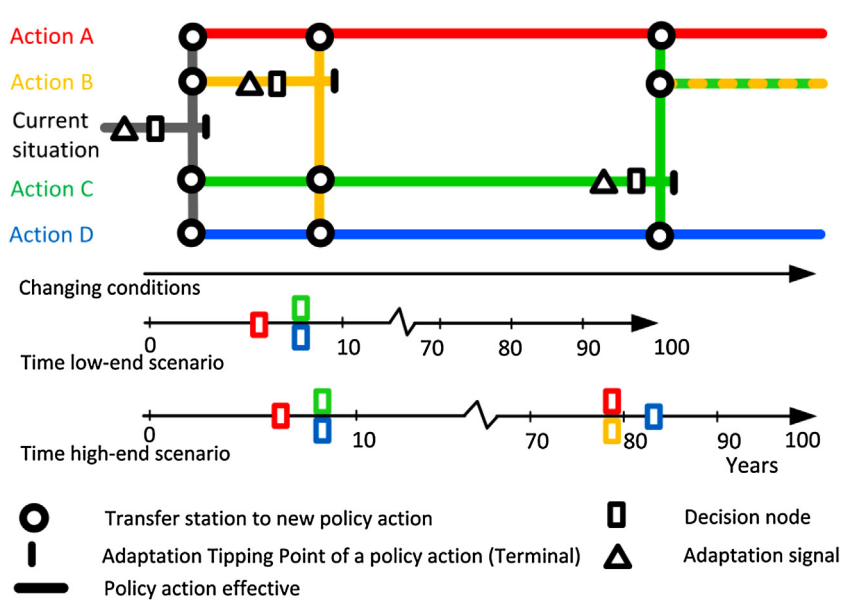

Fig. 1. Key concepts in adaptation pathways approaches – Dynamic Adaptive Policy Pathways example. (source: Haasnoot et al., 2015a,b, Fig. 2.1).

Mintzberg (1978) showed, in a seminal study in a car manufacturing industry, how realized strategies differed substantially from what was originally planned.

Not only is implementation likely to be different from planned strategies, it is also difficult to learn what happens during implementation and what causes divergence between the plans and their implementation. This is, for an important part, due to the key role played by operators and 'street-level bureaucrats' (Gofen, 2014). For instance, consider an asset management strategy for a water service provider that stipulates that replacements of assets above a certain threshold amount need to be centrally coordinated and approved to ensure efficiency. In implementation, this leads system operators and maintenance engineers to order sub-parts for replacements separately, to bypass the need for higher level approvals, paperwork and delays. This enables more easy replacements and increases the reliability of the system, but also leads to higher costs, as these smaller orders are more costly (Breeveld et al., 2013). In another case, Van der Zaag and Rap (2012) show how irrigation policies are critically shaped by the implementation decisions made by the local operators who decide on distribution of flows within the system. Stetler et al. (2006) refer to the black box of implementation, and stress the importance of collaboration between evaluators and implementers to open this black box. Hence, if we monitor only the signposts and triggers that were predefined during planning, we miss a lot of what is going on in actual implementation, and how this reshapes strategic plans.

2.3. The long-term horizon of adaptation pathway plans

Adaptation pathways approaches have a long-term focus. This demands a system for monitoring and evaluation that is sustained over long periods of time, as a contributor to long-term collaborative learning processes (Leeuw and Furubo, 2008). However, although stability is needed for such long-term evaluation arrangements, goals and societal values change over time (Offermans et al., 2011; Eisenhauer, 2016). This introduces a tension between stability and dynamics similar to the tensions observed by Kallis et al. (2009) with institutions that can support adaptive learning and flexibility, while also providing sufficient stability and accountability in processes of adaptive governance.

On the one hand, a clear and stable system of monitoring indicators and evaluation procedures is needed to enable the various parties involved to organize their monitoring efforts, to develop an understanding of the meaning of monitoring information, and to be able to analyse longer-term trends and developments. Jacobson et al. (2014) report how too frequent changes in monitoring and evaluation requirements lead to fatigue and cynicism among those who have to deliver and analyse the monitoring information. On the other hand, stable monitoring and evaluation systems are more at risk of becoming part of standard routines; systems that have to be satisfied with data and periodic reports rather than systems that support deliberate learning. These routine processes may over time result in perverted systems, that themselves do not produce trustworthy information for learning about policy implementation and effectiveness (De Bruijn, 2007).

Once actions/strategies are implemented the effects can be different than initially foreseen. Monitoring systems that focus only on pre-specified impacts and objectives may result in 'designed blindness' that ignores unforeseen but critical impacts (Friedman, 2001).

2.4. The wickedness of adaptation problems and the associated multi-actor policy environment

Adaptation pathways typically deal with 'wicked problems' (Kwakkel et al., 2016), characterized by high levels of complexity, uncertainty, and value divergence. This means actors tend to disagree about what the core of the problem is, may have different strategic intentions, and are likely to entertain different views about the key mechanisms and causal relations that determine how policy interventions translate into policy impact (Rittel and Webber, 1973).

Wicked problems call for collaborative learning arrangements (Head, 2008) in line with the constructivists and interpretative approaches to evaluation like those developed by Guba and Lincoln (1989). However, bringing different actors together in a collaborative learning process requires more than just a new organization or platform (Kallis et al., 2009). Also, although collaborative learning can provide novel insights based on open and equal exchanges, it may be very time consuming and demanding on the involvement of a large range of actors (Rijke et al., 2012).

Adaptation pathways approaches thus far tend to under-appreciate the presence of conflict and antagonism in political relations that complicates collaborative learning (Eisenhauer, 2016: 216). Where adaptation pathways address complex issues and involve multiple parties, the official planning objectives may not cover the outcomes of interests for all involved. This applies especially where significant externalities and side-effects may occur (Gysen et al., 2006). The officially agreed adaptation objectives may guide the public agency that has the agreed policy adaptation pathways as its core responsibility, but other actors may cooperate or hinder implementation for other reasons. For instance, in the asset management strategy referred to above, the focus on cost-control in the asset management department creates a conflict with the focus on reliability and minimal risk of system failure among operators, which negatively influences the implementation and the effectiveness of the asset management strategy (Breeveld et al., 2013). This presence of competing objectives and different perspectives are common for natural resource management and sustainability problems (e.g. Offermans et al., 2011). Therefore, a collaborative learning process should recognize that it may not be possible to arrive at one single set of objectives and causal assertions as the one and only basis for monitoring and evaluation (Hermans et al., 2012).

Monitoring and evaluation is a key part to informed collaborative learning, but it also comes at a cost. Collaborative learning can be seen as a public good, whereas the ongoing collection and processing of monitoring data requires investments by individual organizations and professionals. This easily leads to tensions (Levine and Sagedoff, 2006), especially since the cost of monitoring efforts is easily underestimated when designing M&E programmes, "especially at the local level (e.g. local government) where the most detail is required" (Jacobson et al., 2014: 54).

2.5. Key challenges in monitoring and evaluation of adaptation pathways

All in all, it is clear that collaborative learning about the implementation of adaptation pathways needs to be informed by monitoring and evaluation arrangements, and that there are many threats and challenges to its success. Table 1 summarizes these challenges, and suggests a first direction of where to look for responses, which we discuss in the next section.

3. Responses to challenges

3.1. Approach for the design of monitoring arrangements for adaptation pathways

The challenges highlighted in Table 1 above point to important trade-offs and some fundamental tensions, which cannot be resolved with a single specific procedure. However, we can think of

Table 1
Challenges in the design of monitoring arrangements for adaptation pathways.

Challenges	Relevant literature		Where to look for responses?
	Adaptation pathways	Planning, monitoring and evaluation	
Implementation			
Adaptation plans are not implemented as planned; realized pathways may differ.	Wise et al. (2014); Van der Bruggen and Roosjen (2015)	Mintzberg, (1978); Waldner, (2009)	Adaptation pathways: signposts and triggers to signal key divergence from original plans
Black box of implementation, with operators as important source of information	Only implicit, e.g. in Van der Zaag and Rap (2012); Breeveld et al. (2013); Jacobson et al. (2014)	Stetler et al. (2006); Gofen (2014)	Participatory evaluations to enable more inclusive monitoring and evaluation processes
Long-term systems			
Tension between stability and change (changing values, new insights and unforeseen developments)	Kallis et al. (2009); Offermans et al. (2011); Eisenhauer (2016)	Leeuw and Furubo (2008); Friedman (2001)	Adaptation pathways to enable stability and flexibility around pre-defined adaptation decisions and tipping points
Frustration and cynicism from frequent changing monitoring designs	Jacobson et al. (2014)	Friedman (2001); De Bruijn (2007)	Adaptation pathways to enable degree of stability
Perverted systems and distorted signals		De Bruijn (2007)	Dynamism and openness as design principles
Multiple actors			
Wicked problems: Disagreements about the core of the problem and system mechanisms; different frames and viewpoints	Offermans et al. (2011); Kwakkel et al. (2016)	Rittel and Webber (1973); Guba and Lincoln (1989)	Participatory approaches and collaborative learning
Collaborative learning is time-consuming and demanding	Kallis et al. (2009); Rijke et al. (2012)		Informed and purposeful learning supported by monitoring
No single set of agreed objectives – and many possible side-effects	Eisenhauer (2016)	Hermans et al. (2012); Gysen et al. (2006)	Pluralistic monitoring designs that leave room for different assumptions by different actors
Costs and cost allocation of monitoring efforts	Jacobson et al. (2014)	Levine and Sagedoff (2006)	Reciprocity in collaborative processes

approaches for the design of monitoring arrangements for adaptation pathways, which help the involved actors to find a workable balance for the trade-offs. The approach we propose for this has adaptation pathways as a central element, and is sketched in Fig. 2. It consists of several building blocks, which we explain in the following sections.

3.2. Basic policy and critical assumptions

The starting point is to monitor the basic policy, as the first path on the pathways map. This means monitoring progress in implementation of policy actions, the realization of objectives, and the developments in external factors. In order to keep time and resource demands within reasonable limits, monitoring should prioritize the critical assumptions underlying the basic policy. These are found and prioritized by looking for the important assumptions in a policy design and their vulnerabilities—the ways in which they might be violated or proven wrong (Dewar et al., 1993). Critical assumptions are those that are deemed most important for policy success and for which it is least certain that they turn out to be valid (Mitroff et al., 1979).

Although this focus on critical assumptions cannot include the unexpected or, on its own, does not necessarily yield insights into the blackbox of implementation, it does make expectations and assumptions explicit. Making our expectations explicit helps to see where external forces, policy implementation, or policy impacts develop different from our expectations, and, in this way, it helps learning (see also Argyris and Schön, 1996).

The basic policy and adaptation pathways plan provide an agreed upon starting point for action, but they do not fully capture the learning needs for all involved. Successful implementation of a basic policy will require contributions from various actors, and may have consequence for objectives held by multiple other actors. The most important critical assumptions of those actors should be included in the monitoring design for the basic policy. There are various concepts and methods for this, such as the identification of systems of values, rules and knowledge (Gorddard et al., 2016), causal narrative story reconstruction (Gysen et al., 2006) or comparative cognitive mapping (Hermans et al., 2012). The use of cognitive causal maps fits well with the notion of a basic policy and associated locations of uncertainties as discussed by Walker et al.

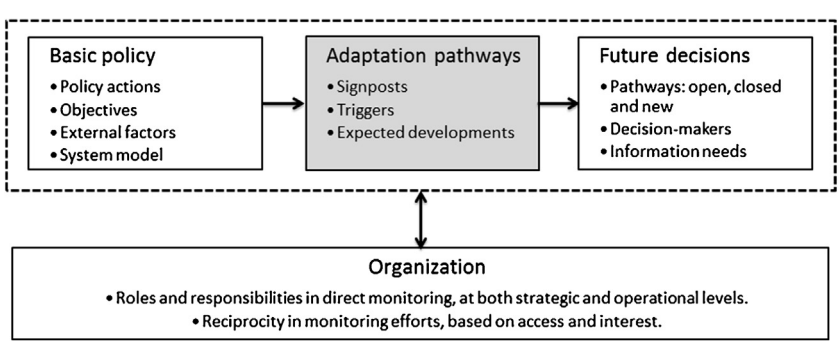

Fig. 2. Approach for the Design of Monitoring Arrangements for Adaptation Pathways.

(2013), which underlies the dynamic adaptive policy pathways approach (Haasnoot et al., 2013).

3.3. Adaptation pathways, signposts and triggers

The connection of a basic policy to longer-term adaptation pathways occurs through the specification of signposts and triggers. Critical assumptions can only be monitored if they are translated into associated variables and indicators. Specifying those indicators allows actors to track progress on pathways and to anticipate upcoming adaptation decisions. Adaptation pathways planning approaches here speak of signposts (indicators) and triggers. Triggers are those values of signpost indicators, individually or in certain constellations, that suggest that critical assumptions may be violated, or at least need attention.

In specifying signposts and triggers, not only ultimate trigger values should be specified, but also expectations regarding the intermediate developments in trigger values over time. This is needed to anticipate emerging adaptation decisions (Hermans et al., 2012; Haasnoot et al., 2015a,b).

As with the specification of critical assumptions, also the specification of signposts and triggers alone will not address some of the key challenges for monitoring. However, it is a precondition to enable and focus learning efforts. This helps use resources in a focused way, especially if it is accompanied by the awareness that some critical assumptions are likely to be proven wrong and that the developed sets of signposts and triggers can not cover the full range of meaningful insights and developments that may unfold.

3.4. Future pathways and decisions

The alternative pathways that have been developed need to be monitored to see if adaptation pathways are still open, if barriers have arisen for certain pathways, and if new pathways are emerging.

Different alternative pathways may involve different decision-makers, implementing partners, and experts. These may also differ from the actors involved in the basic policy. This makes it important to identify the actors who decide about potential adaptations (about the transfer between policy pathways) and the actors who will need to contribute to the implementation of pathway decisions (cf. Van der Bruggen and Roosjen, 2015: 747). Likewise, it is important to identify who is likely to be impacted by future adaptation decisions. If decision-makers and stakeholders are known for the different adaptation pathways, we can assess what monitoring information would help them in making their adaptation decisions.

As part of an adaptation pathways plan, rules and incentives may have been designed to promote or stimulate that certain future options indeed are being kept open (cf. Van der Bruggen and Roosjen, 2015). These aspects need to be included in monitoring and evaluation as well. This means that also here, critical assumptions can be usefully surfaced, as discussed above.

3.5. Organization and reciprocity in monitoring efforts

Finally, it is important to include key organizational aspects in the design of monitoring arrangements. Adaptation pathways

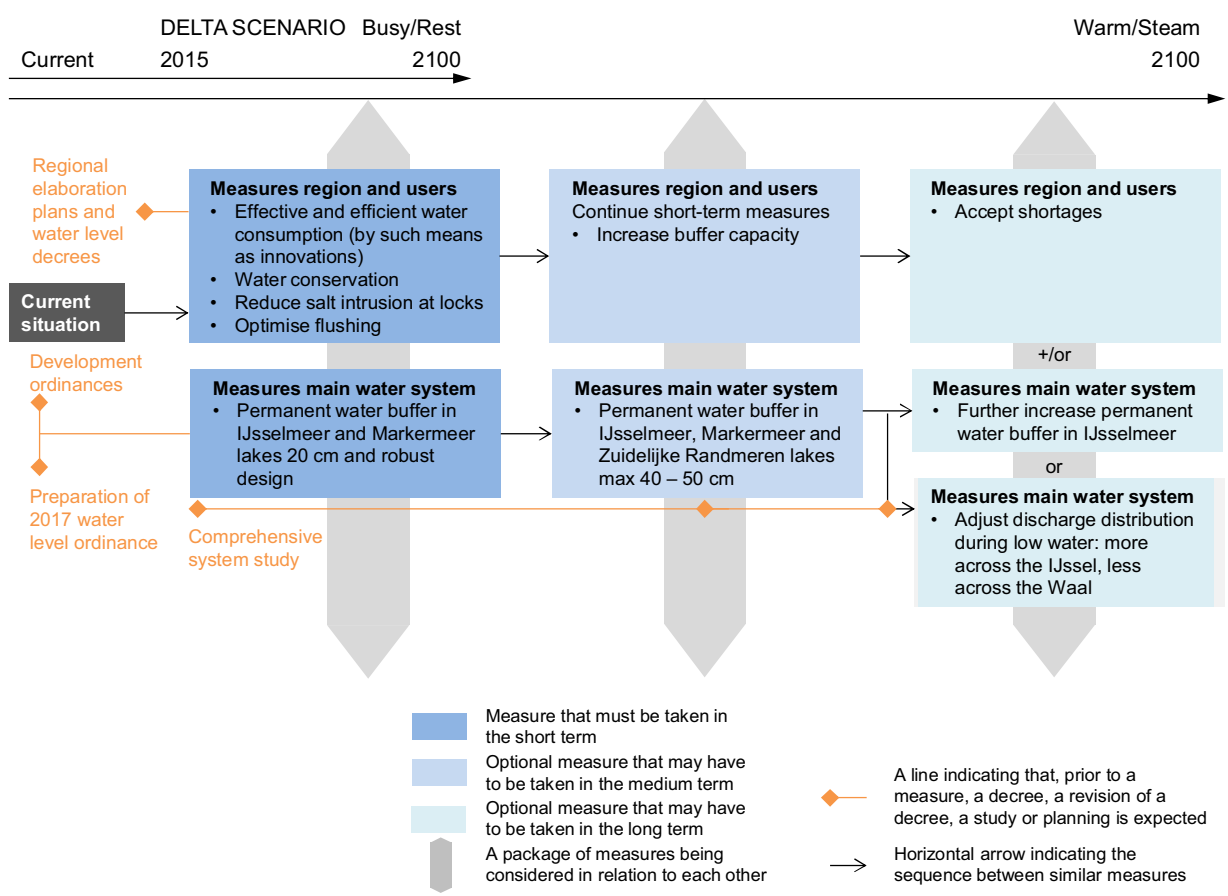

Fig. 3. Adaptation pathways for freshwater supply for the IJsselmeer Region.
(source: Delta Programme 2015, Fig. 5).

assume adaptation actions and decisions by various actors, and asymmetrical relations are likely to exist where information needs and access to information are not well aligned among actors. The actors with decision-making power are likely to be located at the strategic policy-making levels and will typically include national ministries and planning agencies. Important information to support those decisions may exist with scientists and researchers, but also with local government agencies, utility companies and other implementers and street-level bureaucrats.

An effective response to these information asymmetries requires that one not only elaborate the demands for monitoring information, but also look into the costs involved in their supply. Sustainable collaborative learning requires attention for the balance of costs and benefits among parties involved in monitoring and evaluation; *reciprocity* is central here, as this is known to be a powerful social mechanism in the design of new joint procedures or patterns of interaction (Ostrom, 2005).

4. Case of adaptive delta management in the IJsselmeer region

4.1. Purpose and methodology

The key elements in our approach have been applied to the adaptation pathways developed within the Delta Programme for freshwater supply in the IJsselmeer Region in the Netherlands. This provides a proof of concept case study, as a key step in design science research to check if the designed approach holds up against real world complexities (Peffers et al., 2007). For this case study, primary data were collected through various meetings, key informant interviews, participant observation, and the use of secondary case documentation and literature. A series of meetings was held to develop and discuss the case reconstruction. Prior to these workshops, initial findings had been obtained through document analysis, interviews and participant observation of a two expert planning workshops in January and February 2014, where invited experts reviewed and discussed the draft freshwater strategies proposed for the Delta Programme. In-depth interviews were conducted early in 2014 with six key-informants at the national water management authority Rijkswaterstaat and the Delta Programme at the national level, two regional water authorities, a regionally active nature management organization and the regional organization of agricultural businesses. Findings were shared in written form with the interviewed key informants, and were discussed at different venues with both scientific and administrative audiences. These included two interactive workshops in July and October 2015, where the proposed design approach and the initial results were discussed with 10 to 12 representatives of government organizations involved in the national Delta Programme. Details of this case study are reported in Hermans et al. (2016a,b).

4.2. Case introduction: freshwater supply in the IJsselmeer region

The IJsselmeer Region covers the main area around the IJsselmeer and Markermeer lakes. These lakes play an important role in the freshwater supply in the Netherlands, being the largest freshwater reservoir in western Europe. The water level in the lakes is tightly controlled to ensure an optimal mix between different water management objectives, such as flood protection, freshwater supply, recreation, nature and navigation. As part of the Dutch Delta Programme, a nation-wide study to prepare the Netherlands for future climate change and socio-economic developments, a policy decision has been proposed for the IJsselmeer Region that entails more flexibility in the water levels in the lakes, while ensuring a strategic freshwater lens of 20 cm in height. This has to be accompanied by actions of local actors in the IJsselmeer Region

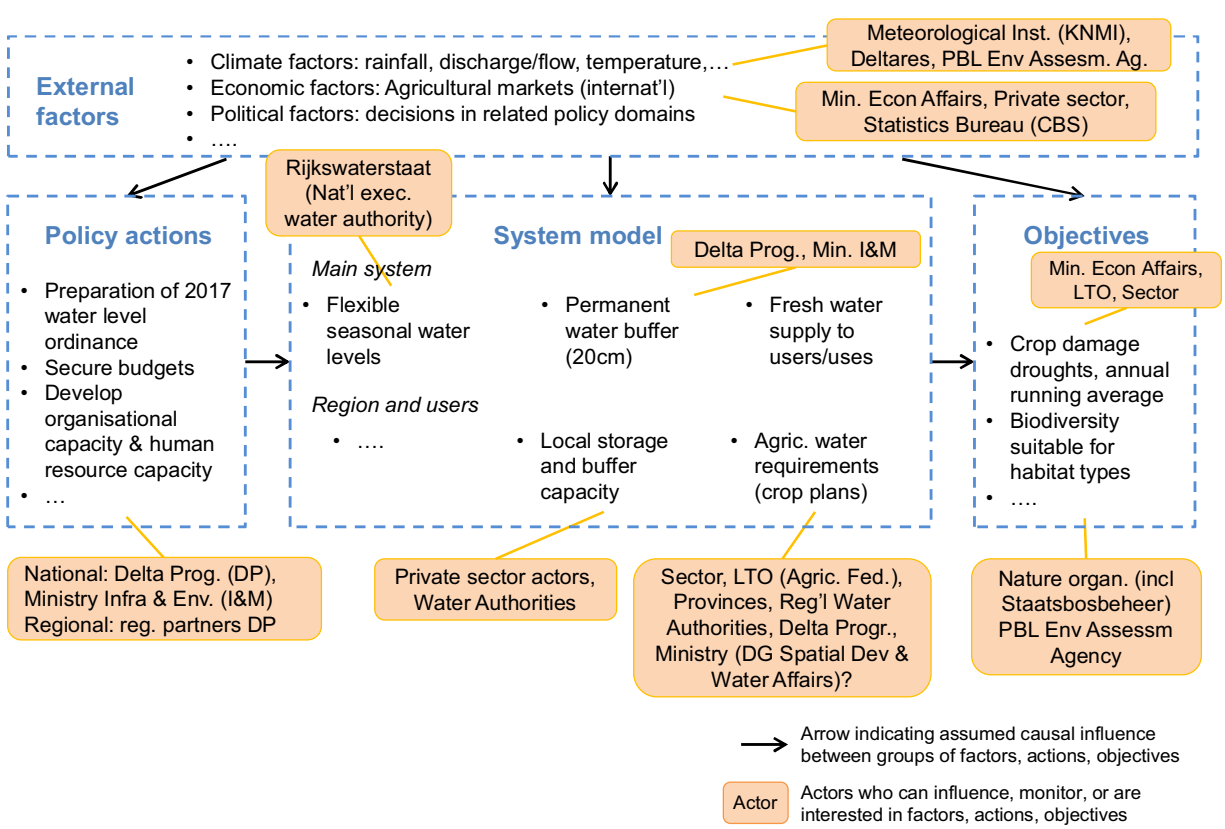

Fig. 4. Key factors and actors for monitoring the basic policy for freshwater supply IJsselmeer Region.

to reduce water demand and to counter salinization (Delta Programme, 2015).

The Delta Programme incorporated the concept of adaptation pathways as part of its adaptive delta management approach. With this approach, the Delta Programme seeks to combine long-term visions with short term decisions and to ensure flexibility in strategies and actions. Several adaptation pathways have been developed by the Delta Programme, including one for the freshwater supply for the IJsselmeer Region (see Fig. 3). The freshwater reserve can be increased to 40–50 cm and more storage capacity could be realized in the region and with local water users–for instance in agriculture and industry. Also, it might be possible, or necessary, to increase the acceptance of freshwater shortages among water users. Another option for the longer term is to reconsider the national allocation of river flows upstream in the Netherlands, changing the volume of freshwater that is flowing to the IJsselmeer lake. This would also affect the freshwater flows to the regions in the western parts of the Netherlands (Delta Programme, 2015).

4.3. Results

4.3.1. Basic policy

The basic policy is built around the left-most measures shown in Fig. 3: effective and efficient water consumption by users, water conservation, reduced salt intrusion at locks, optimising flushing for the regional water system, a permanent water buffer of 20 cm, and a robust design of the lakes IJsselmeer and Markermeer. The lake water level is to be managed in a more flexible and dynamic way during the year, to allow for the optimal combination of freshwater supply, flood protection and nature objectives. Under some scenarios, these measures may last until 2100; under other conditions, they may need to be adjusted and complemented in a few decades of time, as indicated by the top axis of Delta Scenarios in Fig. 3.

A first step in the design of a monitoring system is to translate these measures into our basic policy components and their assumed causal relations: actions, intermediate system factors, objectives, and external factors. Furthermore, to identify the critical assumptions, uncertainties in the assumed causal mechanisms should be identified, as well as their importance and possible unintended consequences.

This first step was very well possible for this case, based mainly on the key informant interviews. Fig. 4 provides an illustrative diagram with key factors depicted in bullets. The connection to the different key actors involved in monitoring is also indicated in this diagram, showing how different actors are involved.

The list of critical assumptions generated through key informant interviews was quite long. Not only did it cover factors and causal relations related to the system model sketched in Fig. 4, but also in relation to procedural aspects, such as (perceived) fairness and legitimacy of policy actions aimed at freshwater management in the IJselmeer Region. These depend in part on efforts in other parts of the country at managing freshwater wisely: freshwater management in lake IJsselmeer, a strategic national reservoir, is connected to freshwater management in other parts of the country.

4.3.2. Adaptation pathways

A next step in our approach, is to connect these critical assumptions to measurable signpost-indicators and trigger-values. This step, when covered in key informant interviews, was more difficult. Results are shown in Table 2.

The last two columns in Table 2 indicate the actors who mentioned a certain trigger value, and the roles these factors play in their own causal reasoning. Note that the indication of "who said what" does not imply that these triggers are of importance only to these actors, but serves as an indication of what thoughts and expressions came to mind most readily for different actor representatives. This illustrates that different actors are interested in different monitoring data and bring different types of knowledge into the process. It also illustrates that sometimes external factors for the Delta Programme, such as developments in agricultural production, can be objectives that are actively pursued for other actors, in this case actors in agriculture.

It is notable that Table 2 is not very lengthy and that the mentioned triggers only specify the *final* threshold values. There is no indication of the expected developments towards those threshold or target values, making it difficult to anticipate

Table 2
Signposts and triggers for progress with basic policy IJsselmeer adaptation pathway.

Signposts (basis for indicators)	Triggers (indicative threshold values)	Who mentioned the trigger values?	Type—for actor who mentioned it (Action, System, Objective, or External factor)
Trends in water supply to region	When fresh water supply from IJsselmeer frequently falls short of intake requirements region	Regional water authority	System
Regional water demands agriculture	2% increase in evapotranspiration expected	Regional water authority	External
Production levels agriculture	2% increase desired in officials plans	Agriculture business organization	Objective
Multi-year average winter levels IJsselmeer lake	Targeted at −0,25 m NAP (NAP: Dutch sea level standard)	State water authority Rijkswaterstaat	Objective
IJsselmeer water buffer over time	If 20 cm water buffer often is not available	Regional water authority	System
Nature species: policy objectives Natura2000	No decline in species ("if you notice a decline, you are already too late")	Nature organization	Objective
Habitat suitability indicators for five characteristic nature types (various specific examples provided)	Suitability of habitat should not decrease	Nature organization	Objective
Design peak discharge near-flood events	No increase planned	State water authority Rijkswaterstaat	Objective (decision about . . .)
Sluice management IJsselmeer	Some room for flexibility in sluice opening (few extra minutes around openings to help nature)	Nature organization	Action
Progress in policy process for freshwater service levels (inform, discuss, decide)	First process cycle to be completed within 3 years	National Delta Programme	Action

upcoming adaptation decisions. This difficulty with specifying intermediate expectations was also observed earlier for another case of long-term water quality monitoring (Hermans et al., 2012). Furthermore, some triggers contain expressions such as "frequently", "often", and "some room", without further specification of more precise threshold values. All this suggests it is difficult to identify specific signposts and triggers.

Two types of difficulties were observed in this case for the specification of signposts and triggers. One difficulty was related to specifying signposts and triggers that help to monitor the validity and correctness of the technical assumptions underlying a policy choice. Under what climate change scenarios should one reconsider the assumed effectiveness of policy actions? Although it seemed fairly easy for interviewees to identify several critical assumptions related to the external factors in of the IJsselmeer basic policy, translating these into measurable signposts and associated trigger values was nearly impossible. This requires a high level of specific technical knowledge and, generally, more thorough study to find reliable and robust signposts or sets of signposts.

A second difficulty was in formulating triggers associated with the (speed of) the realization of policy objectives and policy actions. Signposts come more readily to mind here for each actor, reasoning from its own perspective. Triggers for these signposts indicate levels of acceptance for different parties. For instance, nature organizations considered a decline in the number species unacceptable (Table 2). The specification of these trigger values becomes a political rather than a technical act. Specifying explicit trigger values here is often a sensitive issue. An example is the trigger expressed as: "When fresh water supply from IJsselmeer frequently falls short of intake requirements region" (Table 2). This sounds fairly specific and measureable, but the use of this trigger requires also a specification of the agreed legitimate regional intake requirements. The only specific trigger values here are either those that have been politically agreed (the 20 cm buffer), or those formulated by interest groups to advocate their cause (nature and agricultural organizations).

4.3.3. Future decisions

Different actors have different ideas for future adaptation decisions (Table 3). For now, the officially proposed adaptation pathways as sketched in Fig. 3 provide the joint basis, but if future conditions change, the debate about adaptation decisions will not be confined to the pathways contained therein. Many actors consider adaptation options not yet included in the agreed pathways. This includes a return to a more stable and tightly controlled water level in lake IJsselmeer, which in fact implies returning to the previous water management regime.

The decision-makers are likely to be different for different parts of adaptation pathways. There are agreed procedures, both nationally and regionally, as well as structures and platforms for coordination, consultation and joint decision-making. What is also needed, is a structure in which the need for adaptation decisions and adjustments is being reviewed in a systematic and regular way.

4.3.4. Organization

There are various existing monitoring programmes that yield useful information, bust some new efforts will also be needed. A clear point of attention that emerges is the connection between the national level actors and the regional and local actors. Important actions have to be implemented locally, and important consequences will also need to be monitored locally.

Another finding when looking into organizational roles and responsibilities, is that technical and political signposts and triggers require different processes, with different types of actor representatives. Setting the technical signposts and triggers requires scientific expertise and technical knowledge of the models used to inform policy design. Universities, research institutes, and specialists in government agencies and NGOs will need to play an important role. Setting the political signposts and triggers requires normative statements of what is considered important and what is acceptable in terms of progress and outcomes. This implies a role for political decision-makers and the public organizations responsible for the formulation and implementation of plans.

Problems with the political signposts may be particularly difficult to tackle. Public officials may not wish to pin-down specific trigger-values because of their political implications. Keeping a part of your targets ambiguous and open leaves room for manoeuvre, both towards constituencies but also towards other actors. Pinning expectations down in targets and bandwidth values reduces this room. This reluctance to specify expectations and boundaries of acceptance is not helped when there is a perceived low sense-of-urgency, as was reported in this case and as seems inherent to the long-term focus of adaptation pathways.

5. Discussion and conclusions

We have described an approach for the design of collaborative monitoring arrangements for adaptation pathways, around the analytical core offered by the dynamic adaptive policy pathways approach (Haasnoot et al., 2013). The case study reported here is a first proof of concept for this approach. As such, it offers no full and operational design for monitoring and evaluation. In part, this is due to the difficulties encountered in establishing clear signposts and triggers, especially intermediate triggers. For the organizational components, this is due to the case study design, which focused more on the first three analytical building blocks in the approach as described in Fig. 2, and less on the fourth organizational component.

The case study of adaptive delta management in the Netherlands yields some interesting findings. By and large, it suggests the sketched approach is workable and helps to identify key uncertainties for monitoring and collaborative learning. Earlier

Table 3
Future decisions and alternative pathways.

Future decision options, shaping alternative adaptation pathways	Key actors involved in decision or implementation?
Increase water buffer IJsselmeer region lakes to 40–50 cm	National level policy decision, Rijkswaterstaat to implement
Accept shortage and its damage	Regional and local water users
Adjust discharge distribution main water system: more water across IJssel during low water	National level policy decision, Rijkswaterstaat to implement
Expand mitigating measures of flexible water levels	Rijkswaterstaat, regional organizations
Increase pumping capacity main and regional water system	Rijkswaterstaat and regional water authorities
Adjust water level ordinance lake IJsselmeer	National level policy decision, Rijkswaterstaat to implement
Return to stable water levels in lake	National level policy decision, Rijkswaterstaat to implement
Raise dikes: more expensive but less vulnerable than reliance on pumping	National and regional level policy decision. Rijkswaterstaat and regional water authorities to implement

discussions of adaptation pathways, certainly in relation to climate adaptation and adaptive delta management, focused almost exclusively on the uncertainties in the external policy environment (e.g. Hallegatte, 2009; Reeder and Ranger, 2010; Hermans et al., 2016a). The case application suggests also the implementation of policy actions, and the assumed internal causality in system models as important sources of uncertainty that need to be covered in monitoring arrangements.

An important part of these additional uncertainties has to do with the roles and activities of various actors. They implement actions and influence the causal mechanisms that operate within a system. These actors are part of the decision-making and implementation process, and hence are not some external force beyond the sphere of influence. This emphasizes again that the multi-actor dimension is a crucial part for collaborative learning about adaptation pathways. Our design approach helps to effectively incorporate this dimension by providing a structure where actors can be linked to factors, signposts and future adaptation pathways.

Although the identification of critical assumptions in basic policies, associated signposts, and key organizational elements was feasible, defining trigger values for signposts was difficult. The practical use of signposts and triggers in adaptive policy pathways, requires that expert knowledge is mixed with political statements of what is societally acceptable. Here, our case study suggests the need for an important conceptual distinction between *technical* and *political* signposts and triggers. Technical signposts help to monitor and learn about the external environment and the inner workings or causal mechanisms assumed in a system. Political signposts monitor the progress in the implementation of agreed policy actions and the realization of policy objectives. Technical signposts are commonly accepted in adaptation pathways approaches, but our findings also point to the importance of political signposts and triggers, associated with the normative evaluation of progress in the implementation and the realization of objectives. Identifying practical trigger values for these two types of signpost variables requires different approaches and the involvement of different types of actors.

Overall, we believe our design approach adds value to existing monitoring practices, by enabling monitoring arrangements that take into account the presence of multiple actors in decision-making, implementation, and learning. The approach sketched here is not the only option, and clearly, further research remains needed. A non-exhaustive list of important topics for further research includes linking the analytical and political streams more effectively in practice, for instance through 'Living Labs' where various actors can collectively experiment and learn about governance innovations (Voytenko et al., 2016), tackling the difficulties around the reduced sense of urgency in long-term planning processes (Roovers and Van Buuren, 2016), the analytical development of suitable technical signposts (Haasnoot et al., 2015a,b), and investigating the applicability of this approach beyond the Netherlands, Europe and western countries more generally.

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