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Room for the River: a stepping stone in Adaptive Delta Management

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This paper explores how the Room for the River Program contributes to the introduction of adaptive delta management (ADM) as applied by the Delta Program in The Netherlands. The concept of Room for the River is based on a holistic, integrated approach embracing a multi-functional river in which flood safety is realized in combination with other values such as landscape, environmental and cultural values. This new approach acknowledges the need for learning (which is a key feature of adaptive management) and more flexibility to deal with an uncertain future as river widening inherently provides future flexibility. On the basis of the results presented in this paper it is argued that Room for the River can be considered a stepping stone in ADM of the Delta Program as it has become the new standard for flood risk management in the Netherlands to take a system approach, embrace experimentation and learning and involve multiple stakeholders. Within the development and implementation of Room for the River these enabling elements, have influenced and shaped the institutional processes and practices on which the Delta Program is founded and of which new concepts and approaches could emerge (such as multi-layer safety, adaptation pathways). This evolutionary process of strategy development has resulted in the following unique features of ADM of the Delta Program: 1) short term actions are linked to long term goals; 2) flexibility is valued and incorporated in strategic policy-making; 3) multiple strategies are considered in a rational manner (adaptive pathways); and 4) different investment agendas are inter-linked. These features may also provide guidance for other countries that are attempting to reform their flood risk management strategies.

Key words: adaptive management, multi-level governance, flood risk management

1. Introduction

It is increasingly being recognized that flood risk management approaches should be able to respond to changes in the natural and socio-economic environment (Ashley et al., 2012; Pahl-Wostl, Kabat, & Möltgen, 2007; Zevenbergen et al., 2012). They should perform well under various potential futures as there is inherent uncertainty about the magnitude of the drivers of flood risk. Specifically river basins are highly dynamic and complex systems (Downs, Gregory, & Brookes, 1991). The challenges for flood risk management strategies of river basins are manifold, as water safety issues interact with a wide range of

environmental and socio-economic sectors including health, agriculture, biodiversity, industry, navigation and tourism. In addition, in trans-boundary river basins differences in legal frameworks, historical and cultural backgrounds add to the complexity (Timmerman & Langaas, 2005). Flood risk management of river basins requires a flexible and adaptive programmed approach including the supporting capabilities such as integrated and adaptive policy frameworks and the institutional capacity at multiple levels and across different jurisdictions and countries to exploit the interactions between these institutional levels, create synergies and avoid undesired outcomes (Huntjens et al., 2011; Rijke, et al., 2012). The flexibility depends on the capacity of the decision makers to learn from new information and their willingness and ability to revise investment decisions based upon that learning (e.g. Gersonius et al., 2010).

Started in 2003, the Thames Estuary 2100 (TE2100) project is probably one of the first to propose an adaptive approach to manage flood risk. The project aims to protect London and the Thames Estuary from tidal flooding and proposes a series of possible interventions until 2100 that can cope with large ranges of change if needed (Reeder & Ranger, 2009). This approach has demonstrated to be instrumental for decision makers to understand the suite of options open to them and how they can be combined into 'decision pathways' that create a portfolio of measures through the century (Reeder & Ranger, 2009). Inspired by TE2100, the Dutch Delta Program adopted this adaptive approach (referred to as Adaptive Delta Management (ADM)) to deal with the difficulties of anticipating climate change and socio-economic developments in protecting the Netherlands against flooding and to safeguard future fresh water supply (Deltacommissaris, 2012). ADM builds upon the theoretical principles of adaptive management (AM) and includes the exploration of adaptation pathways (Rijke et al., 2014). AM is defined as a systematic process of learning from the outcomes of management actions, accommodating change, and thereby improving management (Armitage et al., 2008; Gunderson, 1999; Holling, 1978). Adaptation pathways supports decision making on short term actions while keeping options open to step up adaptation measures on the longer term (Haasnoot, Kwakkel, Walker, & Ter Maat, 2013).

After the near-miss floods in 1993 and 1995, the Room for the River program has been developed in The Netherlands in the first years of the 21st century. Room for the River marks the transition from dyke improvement to an integrated approach directed to reduce flood risk and to deliver spatial quality (Verkerk & van Buuren, 2013). Because Room for the River provides more space for rivers through river widening it is generally conceived as an approach that is more flexible to adjust to uncertain future needs than the traditional approach of reinforcement. Moreover, it is considered the first programme in the Netherlands to adopt a multi-level governance approach in which NGO's and private stakeholders in different disciplines (e.g. water safety, planning, agriculture, nature) and authorities at national, regional and local levels are actively collaborating to reduce the flood risk and to increase the spatial quality by creating more space for the river (Van der Brugge, Rotmans, & Loorbach, 2005).

Therefore, the Dutch Room for the River program is considered an "exemplary project" for adopting new governance approaches by the Ministry of Infrastructure and Environment (Van der Brugge et al., 2005). For example, the Delta Program is using Room for the River as an example for organizing collaborative governance and how to deliver integration of objectives across spatial and temporal scales (Rijke, 2014; Van Herk, 2014). Hence, the lessons from the Room for the River Program are perceived to have great relevance for future water management in the Netherlands and abroad.

This paper attempts to analyze the relevance of AM to the development and application of the Room for the River Program and to reconstruct how the latter has influenced the institutional settings, regulating policies and practices on which the Delta Program (c.q. ADM) has been built. Following a brief description of the background and main features of the Room for the River Program in Section 2, we will review in Section 3 the literature on AM. Section 3 aims to identify its key features (enabling elements) and practical relevance to natural (water) resource management such as river restoration. In the following Sections 4 we will analyze how these enabling elements have influenced both the Room for the River Program and the Delta Program. Based on the results of this analysis we postulate in Section 5 the thesis that the Room for the River Program can be seen as particularly influential to the development and application of ADM. Moreover, we conclude that this program can be considered as a stepping stone in the evolutionary process that leads to integrated flood risk management in the Netherlands as further developed in the Delta Program.

2. The Room for the River Program

In 1995, extreme river water levels nearly caused dyke breaches and led to the evacuation of 250,000 people and 1 million cattle. This created enhanced awareness amongst the public, politicians, public administration and water professionals that nature cannot be controlled and that new ways of managing rivers are required; i.e. through creating more *space for rivers* to discharge their flows. Amongst others, this led to the initiation of the 2.2 billion Euro Room for the River Program, which started its detailed design phase in 2006. The Room for the River Program is currently in the realisation phase and is scheduled for completion by 2015-2016 (PDR, 2011). It has a dual objective of:

- improving safety against flooding of riverine areas of the Rivers Rhine and Meuse by accommodating a discharge capacity of 16,000m^3/s for the Rhine and 3,800m^3/s for the Meuse;
- contributing to the improvement of the spatial quality of the riverine area.

At the start of the program, a set of 39 locations (projects) was selected to create more room for the rivers through, for example flood by-passes, excavation of flood plains, dyke relocation, and lowering of groynes (Figure 1).

The Room for the River Program falls under the more widely applied practice of "Integrated River Basin Management (IRBM)". This typically refers to a comprehensive

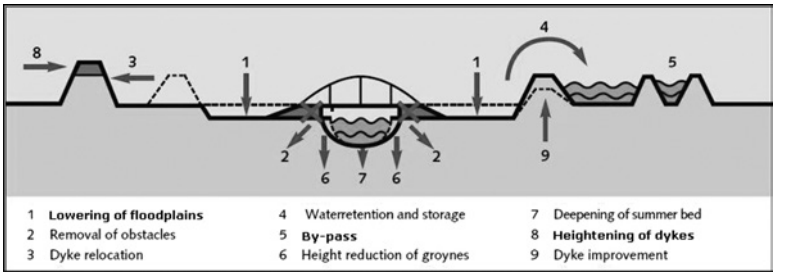

Figure 1. Measures that are applied in the Room for the River Program
(Source: Room for the River Program Office)

and coordinated approach to the management of river systems (Downs et al., 2005). It follows from the above that Room for the River can be defined as a comprehensive water management approach that aligns multiple objectives such as providing safety, transport capacity, opportunities for recreation, enabling nature, water supply, facilitating economics, safeguarding aesthetics and water quality play an important role (Downs et al., 1991; Opperman et al., 2009; Saeijs, 1991). Integrated river basin management particularly takes into account the interplay between both water and land use functions requiring integration across spatial scales. In this context it is useful to contrast IRBM to AM. IRBM pursues the integrated and coordinated management of water and focuses on balancing goals and views of stakeholders, whereas AM is rooted in the co-production of knowledge and acceptance of uncertainty. With respect to the first, there is indeed a cautious trend towards more functional integration in The Netherlands as exemplified by Room for the river in which ecological and spatial values become more strongly connected to the primary function of the Dutch water system in terms of safety and transport. Integration in water management shows a strong path dependency (Verkerk & van Buuren, 2013). The second objective of Room for the River to contribute to spatial quality has stimulated interlinking flood protection with local and regional investment agendas. At the level of the individual projects (39 locations) synergies were sought to combine the creation of more room for the rivers through, for example flood by-passes, and dyke relocation with interventions that increased the spatial quality.

Compared to other large projects in the water and infrastructure sectors, the Room for the River Program performs well in terms of achieving project objectives and the overall process of delivery (satisfaction) (Flyvbjerg, Skamris Holm, & Buhl, 2002; Hertogh & Westerveld, 2010; Rijke et al., 2013; Van Herk, Rijke, Zevenbergen, & Ashley, 2013). It is on track to achieve its (local) project objectives without budget over-run or major time delay as well as the program objectives for flood safety and spatial quality (Rijke et al., 2012). The majority of individuals who were actively involved in the program (e.g. decision makers and project officers across all government levels) are satisfied with the process and output of the program (Rijke et al., 2012; Van Twist et al., 2011).

3. Adaptive Management: a literature review

Adaptive management has emerged in the US since the 1990s to support natural resource management policy as a response to short-comings of the 'traditional' approaches to manage natural resources (Holling, 1995; Walters & Holling, 1990). One of these shortcomings has been the inability of "science" and "management" to interact effectively and to informing and learning from each other. In addition, natural resource management has been continuously afflicted by crises caused by a focus on single targets, piecemeal management policies, and a lack of flexibility in institutional arrangements (Walters & Holling, 1990). Adaptive management aims to overcome these problems as it strives to systematically integrate scientific knowledge into environmental decision making by using management experiments and adopting cycles of improvement of understanding and management. Hence, it entails a systematic and structured process for continuing improving management policies and practices acknowledging our limited understanding of natural system's behavior (Armitage et al., 2008; Holling, 1995).

There are several, often overlapping, interpretations and definitions of adaptive management in terms of scope (strategy, decision support), emphasis (stakeholder engagement, role science and scientific experiments and process design) and spatial scales and ecosystem boundaries (such as forests, rivers, wetlands, and marine life (fisheries)) (see (Table 1). Yet there remains considerable confusion about what adaptive management entails, and how to actually make resource decisions adaptively (Williams, 2011). In spite of the various interpretations and definitions, it appears from Table 1, which reflects the results of a literature review in adaptive management covering two decades of history of development and application, that the overall aim of adaptive management has not significantly changed since it's early days. It follows from Table 1 that AM aims *to increase the adaptive capacity to learn from and better cope with uncertainty affecting the management of natural (water) resources* (as opposed to seeking optimum solutions).

In most cases adaptive management is seen as a structured, iterative, learning-based process involving the fundamental features of learning and adaptation leading to both improved understanding of the (resource) system and to improved management based on that understanding. Relevant to the context of learning is to make a distinction in the ways learning-based decision making is conceived in the various interpretations of adaptive management (Levine, 2004; Walters & Holling, 1990; Williams, 2011): *passive adaptive management (monitor and modify)*, monitoring data contributes to improvements and refinements, and *active adaptive management*, all management actions are deliberate experiments and different management actions are implemented to test a range of hypotheses. The feedback between learning and decision making entails an adaptive cyclic process which is an essential feature of adaptive management, with learning contributing to management by helping to inform decision making, and management contributing to learning through interventions that are useful for investigating resource processes and impacts (Rijke et al., 2012; Van Herk et al., 2013).

Table 1
Definitions and interpretations of adaptive management (modified and updated from Levine (2004))

Definitions/interpretations	Sources
AM is an innovative technique that uses scientific information to help formulate management strategies in order to 'learn' from programs so that subsequent improvements can be made in formulating both successful policy and improved management programs.	Halbert (1993). How adaptive is adaptive management? Implementing adaptive management in Washington State and British Columbia.
AM is a structured process of learning by doing that involves more than simply better ecological monitoring and response to unexpected management impacts. It should begin with a concerted effort to integrate existing interdisciplinary experience and scientific information into dynamic models that attempt to make predictions about the impacts of alternative policies.	Walters (1997). Challenges in Adaptive Management of Riparian and Coastal Ecosystems.
AM is an approach to managing complex natural systems that builds on learning—based on common sense, experience, experimenting, and monitoring—by adjusting practices based on what was learned.	Bormann et al. (1999). Adaptive Management In: Ecological Stewardship: A common reference for ecosystem management.
AM is a systematic process for addressing the uncertainties of resource management policies by implementing the policies experimentally and documenting the results.	MacDonald et al. (1999). AM Forum: Linking Management and Science to Achieve Ecological Sustainability.
AM treats actions and policies as experiments that yield learning (it mimics the scientific method: specifies hypotheses, highlights uncertainties, structures actions to expose hypotheses to field tests, processes and evaluates results, and adjusts subsequent actions in light of those results), and embraces risk and uncertainty as opportunities for building understanding that might ultimately reduce their occurrence.	Stankey et al. (2003). Adaptive Management and the Northwest Forest Plan: Rhetoric and Reality.
AM is "learning by doing" with the addition of an explicit, deliberate and formal dimension to framing questions and problems, undertaking experimentation and testing, critically processing results, and reassessing the policy context that originally triggered investigation in light of the newly acquired knowledge. The concept of learning is central to AM. It is a process to accelerate and enhance learning based on the results of policy implementation that mimics the scientific method: experimentation is the core of adaptive management, involving hypotheses, controls and replication. It is also irreducibly socio-political in nature.	Stankey, Clark, and Bormann (2005). Adaptive Management of Natural Resources: Theory, Concepts, and Management Institutions.
AM is a formal process for continually improving management practices by learning from the outcomes of operational and experimental approaches. Four elements of this definition are key to its utility. First, it is adaptive, and intended to be self-improving. Second, it is a well-designed, formal approach that connects the power of science to the practicality of management. Third, it is an on-going process for continually improving management, so the design must connect directly to the actions it is intended to improve. Fourth, although experimental approaches can be incorporated into adaptive management effectively, operational approaches and scales are emphasized to permit direct connection to the efforts of managers.	Bunnell et al. (2007). Forestry and biodiversity—learning how to sustain biodiversity in managed forests.

Table 1
(*Continued.*)

Definitions/interpretations	Sources
AM emphasizes learning and uses structured experimentation in combination with flexibility as ways to achieve this. Co-management emphasizes the sharing of rights, responsibilities, and power between different levels and sectors of government and civil society. Adaptive co- management, then, is a novel combination of the learning dimension of adaptive management and the linkage dimension of co-management.	Huitema et al. (2009). Adaptive Water Governance: Assessing the Institutional Prescriptions of Adaptive (Co-)Management from a Governance Perspective and Defining a Research Agenda

In most of the definitions, experimentation is seen as part of AM. It is important to note here that experimentation has two interpretations which are both described in the adaptive management literature. One is as a research methodology to test hypotheses on (eco)system response to different management interventions (e.g., Lee, 1999) and the other is as an approach to management (management itself is seen as an experiment) acknowledging that management is always based on incomplete and uncertain information (Pahl-Wostl, 2007).

It also follows from the above that AM is likely an effective strategy if (i) uncertainty is acknowledged and 'information gaps' are identified, and thus when learning is needed to achieve certain management goals, (ii) there are good prospects for learning and experimenting in order to narrow down information gaps over time, and (iii) the socio-economic and physical changes warrant to adjust management directions (interventions) as a consequence of lessons learnt (Doremus et al., 2011). In addition, the majority of the literature cited in Table 2 also emphasizes the need to adopt a system (cq an ecosystem) based approach as AM is designed to improve understanding of how a *system* works (e.g. Bormann et al., 1999; Bunnell et al., 2007; Lee, 1993; Walters, 1997). It recognizes the complexity of the system being managed, and the need to take the interactions that exist between potential multiple spatial and temporal scales and the degree of uncertainty inherent in our natural and social systems into account. Models and scenarios are often used to test hypotheses about system behavior and to explore the consequences of (policy) interventions. These explorative assessments are the basis for learning and adjustments in time (Berkes, 2009; Haasnoot et al., 2013; Klijn, de Bruijn, Knoop, & Kwadijk, 2012; Lee, 1993; Pahl-Wostl, 2007). Many researches have emphasized the relevance of stakeholder participation throughout the AM cyclic learning process of policy formulation, implementation, evaluation and adjustment (Huitema et al., 2009; Lee, 1993; Pahl-Wostl et al., 2007; Van Herk, Zevenbergen, Gersonius, Waals, & Kelder, 2014). It is not surprising that there is a growing interest in adaptive management in many river restoration efforts and more recently in flood management programs. Well know examples of the first category are typically from the US including the Mississppi River Basin (National Research Council, 2004), the Colarado river (Colier et al., 1996) and Colombia River Basin (Lee, 1993). Examples of

the second category comprise the previously mentioned Thames Estuary project (TE2100) and the Dutch Delta Program.

In spite of these promising prospects several attempts to develop and implement adaptive management have failed due to institutional constraints, a lack of stable (long-term) funding and resources for information gathering and monitoring, reluctance of decision makers to admit and embrace uncertainties in making policy choices, and lack of leadership in implementation (Lee, 1999; Walter, 2007). Although extensive evidence for success is still lacking, it follows from the above that, three elements seem to be conditional for the development and implemention of an adaptive management approach. These elements, referred to in this paper as enabling elements, are: (i) the adoption of a system approach, (ii) participatory decision making and (iii) learning and experimentation .

4. Enabling elements for adaptive management in Room for the River

In this section, we describe how the enabling elements for adaptive management were implemented in Room for the River and we assess the influence of these enabling elements on the development and implementation of the program.

The adoption of a system approach; River systems can be conceived as dynamic assemblages of interacting components, organized on multiple scales of space and time (Levin, 1992). Developing sustainable management approaches to such systems warrants an understanding of what constitutes to its resilience and how human intervention might affect it. In the Room for the River Program the river system has been considered broadly to include the socio-economic and physical characteristics at all relevant spatial scales and their relation to the discharge regime. A key methodological development has been to deal with these processes from an integrated system perspective for estimating the effects of combinations of measures on the flood levels along the river. This methodological development has led to the provision of a simple and user-friendly tool, the so-called “Planning Kit” for Flood Management along the Rhine Branches. This planning tool allows the user to make a selection of combinations of all the available measures and immediately visualize the result of implementing these measures (WL Hydraulics, 2007). In the initiation phase of Room for the River, some 700 individual river improvement measures, which have been suggested by stakeholders to contribute to providing room for the river, were analyzed. Based on these assessments a package of about 40 measures has been selected to be implemented. Thanks to its transparency and simplicity the utility of the Planning Kit has been demonstrated: it proved extremely important in facilitating the public discussion—as well as that among professionals – to identify a portfolios of measures in the initial (planning, design and decision making) phase of the program (Rijke et al., 2012). The process of collaborative planning, design and decision making has established above all legitimacy and trust and thus commitment among the stakeholders (Van Herk, 2014a). In successive long-term projections the Planning Kit has also been instrumental to identify alternative actions for the future. A system approach’s perspective on Room for the River also supported the paradigm shift from flood protection to integrated flood

risk management in the Netherlands: it contributed to the insight that Room for the River reduces flood risk and not only the probability of flood occurrence but also the impact of flooding (Klijn et al., 2012).

Participatory decision making; Integration inherently comprises collaboration between multiple stakeholders and multiple disciplines (Potter et al., 2011; Van Herk et al., 2013). The Room for the River Program has adopted a new (multi-level) governance approach in which government agencies in different disciplines (e.g. water safety, planning, agriculture, nature) and at national, regional and local levels and other stakeholders are actively collaborating (Van der Brugge, 2005). The program uses a mix of centralised (national) steering and decentralised (regional) decision making processes (Ten Heuvelhof et al., 2007). The decision frameworks for establishing improved water safety and spatial quality are set by the national Government, whilst the plans and designs are formulated and decisions are taken by local and regional stakeholders in 34 regional projects. The national government has established a central program office to manage and monitor progress, evaluate quality of designs, and facilitate the regional projects through guidelines, providing expert knowledge, community building, and, where needed, applying political pressure. This approach provided the opportunity for decentralised governments to link local issues, such as new urban developments and the development of natural and recreational areas, with the national water safety agenda (Van Twist et al., 2007). Although it is too early to draw conclusions on the effectiveness of participatory decision-making arrangement of the Room for the River Program (completion is scheduled for 2015) for achieving objectives, the results of a survey amongst participants (n=151) of the Room for the River programme where respondents were asked to rate success factors of RftR for its output and uptake in future programs, using a five-point Likert-based scale, revealed that the multi-level governance approach was conducive in the program's performance (Rijke et al., 2012; Van Herk et al., 2012). Similarly, the survey substantiated that the dual objective of the program created incentives for collaboration and commitment from stakeholders (Rijke et al., 2012; Van Herk et al., 2013).

Learning and experimentation; Decisions in the present have implications for a range of possible future adaptation options. A driving factor behind the development of Room for the River has been the quest for an alternative to dyke reinforcement and heightening to reducing flood risk (Klijn et al., 2012). River widening is assumed to increase flexibility (compared to the traditional approach) as it leaves more options open to manage future flood risk because additional measures such as lowering the floodplains, dyke reinforcement and heightening measures can still be considered in the future. This flexibility allows for adopting lessons learnt about the systems performance and effectiveness of measures. During the initiation phase of the program, an assessment was carried out to assess if Room for the River could accommodate the passage of 18.000m^3/s in the river systems in the future instead of the 16.000m^3/s originally planned for and at what cost. In addition, rough estimates were made to increase the discharge capacity by creating more retention areas in the flood plains of the Rhine (PKB, 2006). It was analysed whether measures could retain their functionality and performance under any

future scenario, such as for a discharge of 18.000m^3/s (Schut et al., 2010; Van Herk et al., 2012a). Hence, the extra *space for the river* that will be needed on the longer term to cope with higher discharges due to projected climate change, will remain available. To date, the cost and benefits of these options and opportunities to adapt have never been quantified as methods for incorporating spatial quality and flexibility in the economic analysis of FRM are still lacking or at best incomplete (Gersonius, 2012). These constraints hamper the appreciation of flexibility. Another constraint to value and opt for (more) flexibility is the limited knowledge on how Room for the River will perform on the longer term compared to the traditional dyke reinforcement approach and at what maintenance cost. The Dutch Central Planning bureau executed a cost benefit analysis based on the direct cost of implementation and the direct benefits in terms of prevented damage (Ebregt, Eijgenraam, & Stolwijk, 2005). This study has revealed that, at particular river branches, Room for the River will be likely more expensive than the traditional approach.

A learning and experimenting approach was adopted through the installation of specific task forces operating at the program level to support transfer and replication of lessons learned from the so-called frontrunner projects to the other projects. These frontrunner projects were conceived as experiments to examine or test new procedures and measures. New insights were transferred through exchange of personnel, guidelines and through network and training events. Also within individual projects experimentation was deliberately factored in. For example, a project that comprised the lowering of approximately 500 groynes along the Waal river was organised into 3 sequential tranches so as to learn from previous tranches in terms of: hydraulic; morphologic and ecologic effects; construction time; market approach. 'Practices' for groyne designs were adapted after the first tranche, based on stakeholder feedback and new insights as to the effectiveness of the designs'.

5. Adaptive management in the Delta Program

In the Netherlands, the national government, water boards, provinces and municipalities are working together on a new Delta Plan on Flood Risk Management (Deltacommissaris, 2015). This program referred to as the Delta Program (DP) comprises a cohesive set of projects (measures) for the short term (up to and including 2028), but also looks ahead to the medium term (up to 2050). This phased approach that ultimately leads to investment decisions, is driven by major uncertainties around future developments and the desirability of responsible financial investment. In this context, it was considered inappropriate to set down measures for the next 50–100 years. Rather, these should be allowed to develop along with new insights and changing circumstances. This insight has prompted the DP to develop a new, adaptive management strategy: the Adaptive Delta Management (ADM) approach (Isoard & Winograd, 2013). The Delta Program defines ADM as "a smart and intelligent way of taking account of uncertainties and dependencies in decision-making on

Delta Management with a view to reducing the risk of overspending or underinvestment". Hence, the objective of ADM is to provide a transparent and structured management process, which takes uncertainty into account in investment decisions of future developments. The Delta Program defines the following objectives and means to operationalize ADM (Deltacommissaris, 2011, 2012, 2015):

- involving multiple stakeholders in joint a decision making process to enhance legitimacy and feasibility;
- taking a systems approach that takes into account various spatial scales;
- adopting a flexible approach in the possible strategies by valuing flexibility with regard to the timing of implementation and allowing to keep options 'open'. This also enables the linking short-term decisions in the broad fields of water, land use and spatial planning to long-term issues in the specific fields of water safety and the freshwater supply and allowing to switch from strategies through adaptation pathways;
- inter-linking various investment agendas and looking for opportunities for mainstreaming with planned investments.)

It is clear from the above that the enabling elements of adaptive management are resonating in the definition and specifications of ADM, albeit that the scope of ADM is broader defined and further specified and detailed with regards to the temporal dimension. In addition to robustness, it specifically mentions flexibility as an essential capacity to deal with uncertainty and exploit opportunities which may emerge over time.

As indicated above, it is pivotal in the Delta Program that decision-making on flood risk management measures needs to take account of a medium to long-term planning horizon as (unforeseen) future developments could influence the efficiency of these measures, for example in terms of use of space. Some developments may lead to higher costs, e.g. building-over spaces that could later have been more usefully deployed for adaptation measures. While other developments could lead to cost reductions, e.g. combining river widening with the replacement of sluices approaching end-of-life. Therefore, decisions on short-term measures should be taken in such a way as to avoid the unnecessary mounting of long-term costs, while agreements should be made on actions that could be linked efficiently (DP, 2011). ADM aims to ensure that any short- to medium-term adaptation decision is set within a framework that will not be maladaptive, if future developments (e.g. sea level rise) are different from what is currently predicted to be 'the most probable' (Reeder & Ranger, 2011). A new element of ADM compared to AM is the inclusion of Adaptation Tipping Points (ATPs). ATPs are defined here as points where the magnitude of change due to external pressures such as sea level rise or peak discharges is such that the current strategy will no longer be able to meet the objectives and thus the measure are no longer adequate (Kwadijk et al., 2010). Combining the defined ATPs with climate change scenarios provide information about the need for additional measures. The ATP analysis can, therefore, help to develop Adaptation Pathways (Haasnoot et al., 2013; Haasnoot, Middelkoop, Offermans, van Beek, & van Deursen, 2012). These refer to a sequence of

measures and potential options, which are triggered before an ATP occurs. Adaptation Pathways provide insight into the options, lock-ins and path dependencies and introduces the flexibility to adapt to a wide range of future developments. Hence, Adaptation Pathways aim to be particularly useful in the context of long-term planning and to link the implementation of strategies for flood risk management with other investment agendas (Rhee, 2012).

In its first years, 2010–2014, the Delta Program has developed a coherent set of Delta Decisions ("Delta Program 2015") and preferred regional strategies for securing water safety (against flooding) and fresh water supplies (Deltacommissaris, 2012). These outcomes will form the basis for a) the modification of national, regional and local policies and b) two implementation plans: the Deltaplan Water Safety and the Deltaplan Fresh Water. The preferred strategies (Adaptation Pathways) typically comprise a set of alternative measures, with options in time, and a script on how to decide later when new information comes available. In this period the Delta Program has engaged public administration at all levels (provinces, municipalities, waterboards) and non-governmental organizations covering both private (shipping, recreation, agriculture etc.) and public interests (nature, landscape, cultural heritage etc.). It is relevant to note here that stakeholder involvement in the Room for the River program has been more prominent than in the Delta Program. This likely due to the long-term horizon and abstract character of the latter (van Buuren, 2013). Following the final decisions on the strategies and measured proposed in the Delta Program 2015, it is likely that its orientation will broaden and also include citizen participation in the near future.

6. Discussion

Based on the features and observations given in the previous sections, in this final section we will discuss the contribution of Room for the River to the development of the Delta Program with a focus on ADM using the three enabling elements of AM. We will first summarize in what way these elements of AM are resonating in both programs. This summary is presented in Table 2. Subsequently, we will analyze how these elements have shaped processes and institutional structures (the causal mechanisms and their consequences) of the two programs (see Figure 2). Finally we will conclude this section to addressing the influence of RftR to the development of the DP.

Table 2 shows that Room for the River and the Delta Program both have (1) adopted a system approach (which in turn provided conditions for the further development and application of a risk-based approach within the Delta Program) in order to manage complexity and uncertainty; this new approach has prompted the need to consider the different spatial scales (*integration of spatial scales*); (2) explore the problem and alternative options from various perspectives, add legitimacy and promote public acceptance through stakeholder participation, cooperation, decentralization, and democratic decision making to achieving *integration of objectives*; and (3) promoted flexibility through experimentation and learning; flexibility, as an attribute which enables to respond to new conditions, is considered

Table 2
Enabling elements of adaptive management (AM) in RftR and DP

Enabling elements AM	RftR	DP
System approach	An enabling element of Room for the River is the importance of taking a whole (hydrological) system approach. This approach is consistent with integrated river basin management where river systems are conceived as dynamic assemblages of interacting components. A system approach's perspective has been conditional for the development and application of a risk-based approach[1] in contemporary flood risk management strategies in general allowing to compare social, economic and environmental costs and benefits.	In the DP the Dutch delta is conceived as a large, complex water system comprising interconnected subsystems of rivers, lakes, estuaries and coastal areas. Interventions implemented in one subsystem will impact other subsystems. The DP has adopted a hierarchy in decision making: decisions on national level (such as on flood protection standards), impose conditions on decisions taken at a regional scale (Van Alphen, Martini, Loat, Slomp, & Passchier, 2009). Drawing from theory and experience with risk based approaches it embraces the multi-layer safety approach. The Deltamodel[2] was used to enable comprehensive analysis of the interaction between different water systems in times of high and low water.
Participatory decision making	Multi-level governance is at the heart of RftR: the central government has commissioned, the regional government has implemented; and a Program Directorate has facilitated public participation through 'kitchen meetings' with farmers, inhabitants. RftR has fostered the creation of a community of professionals from all involved public organizations (Rijke et al., 2012; Van Herk et al., 2012; Van Herk, Rijke, Zevenbergen, Ashley, & Besseling, 2014).	The design, planning and implementation is performed in close collaboration with other administrations and stakeholders. The process of decision-making governs the development of new knowledge. Joint fact-finding is applied to include the knowledge and expertise of all parties involved. In addition, this approach improves trust and acceptance of the measures (Verkerk, Van Buuren, & Teisman, 2014)
Learning and experimentation	RftR program has adopted a *learning by doing* approach and considered both management structures and technical interventions as experimental hypotheses that have been tested through implementation (Van Herk, Rijke, et al., 2014).	Adopting a flexible approach in the possible strategies by valuing flexibility with regard to the timing of implementation. This approach allows to switch from strategies through adaptation tipping points (ATP) and adaptation pathways and requires continuous monitoring and evaluation. Learning and experimentation are explicitly taken into account in the program as an inspirational target albeit that their implementation has not yet been defined. Pilots are explicitly part of the Delta Program (see e.g. the new *Knowledge and Innovation Program Water and Climate*[3].)

[1] Risk based approaches aim to make informed choices to be made based on comparison of expected outcomes and costs of alternative courses of action as opposed to the standard-based approach that focuses on the severity of the flood that a particular asset has been designed for (Sayers, 2002).
[2] Delta model: "*a model for the Delta Program in order to be able to carry out the underlying calculations" (Deltacommissaris, 2012)*
[3] Knowledge and Innovation Program Water and Climate: a new Dutch research program with a dedicated research orientation aiming to support the Delta Program.

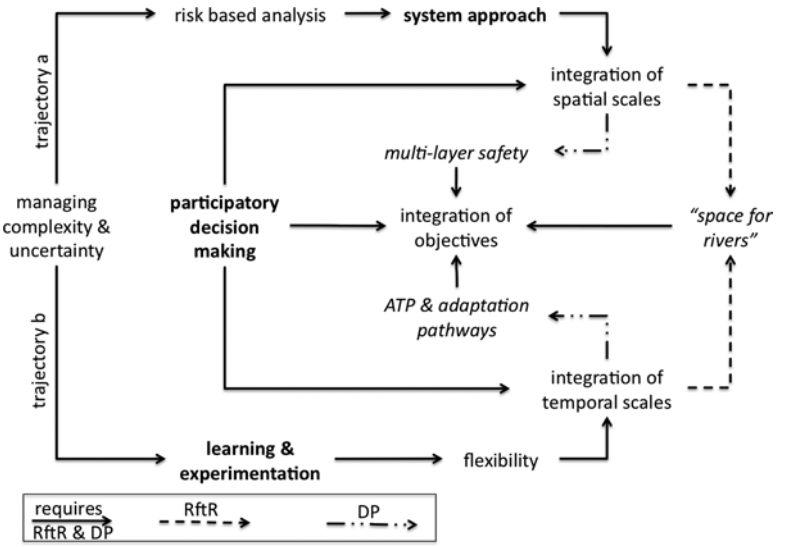

Figure 2. Causal relation diagram visualizing the trajectories which capture the institutional processes (e.g. enabling elements), settings and attributes and their causal relationship of the Room for the River and the Delta Program

as an essential feature of both programs. The ease with which a strategy or system can be adjusted to new conditions requires a process that considers the temporal scales in an integrative way (*integration of temporal scales*); Room for the River promotes learning to increase the effectiveness of the planning processes. On the long-term Room for the River is about the realization of a type of intervention that is more flexible than its alternative (dyke strengthening)[1]. The Delta Program primarily aims for this second type of flexibility.

Based on the results presented in Table 2 two inherently linked, evolutionary trajectories are constructed which show how the enabling elements have shaped the Room for the River program. These trajectories are illustrated in Figure 2 and further described below. Both trajectories evolve out of the awareness that the (river/delta) system to be managed is complex and that its behavior is surrounded by uncertainties (*managing uncertainty and complexity*). It follows from Figure 2 that both trajectories drive spatial and temporal integration and an *integration of objectives on which the Delta Program* is founded.

Trajectory a; The call for a new, holistic approach to manage the challenges posed by complex and dynamic river basins (such as those embodied in integrated river basin management (IRBM)), emphasized the need to embrace a *system approach* in which

[1] It needs to be seen whether this flexible approach can be effective on the longer term: a constraining factor for effective exploitation of flexibility in the context of integrated river basin management is the large year-to-year variations in peak annual river discharges. This may complicate the detection of climate change within the time scales of decision making, especially when it comes to extreme events (Haasnoot et al., 2013).

the river system is conceived as a collection of spatially interconnected subsystems. The adoption of a system approach requiring an *integration of spatial scales,* is an essential step in this process as it has been conditional for the emergence of a new paradigm: *'space for rivers'*. Following the results of two national research programs on flood safety in the Netherlands (WV21[2] and VNK[3]), this trajectory has also resulted in the development of an integrated flood risk-based approach. This approach has been adopted by the Delta Program and is referred to as the concept of *multi-layer safety* (MLS). It addresses in a holistic way the whole safety chain ranging from prevention (1st layer: protection), to preparedness (2nd layer: spatial planning) and finally to emergency response (3rd layer: recovery). Within the Delta Program pilots are currently being executed to further explore the effectiveness of MLS in practice to reducing the residual risk through interventions in the 2nd layer (spatial planning and the 3rd layer (emergency response) (Van Herk, Zevenbergen, et al., 2014).

Trajectory b; The prevailing paradigm was characterized by a 'command and control' regime using hard engineering strategies. The recognition that these management approaches have lead to decreased flexibility and failed to deal adequately with the challenges associated with uncertainties, has prompted the need for new approaches which are reflexive in nature and builds learning into the management cycle: *learning and experimentation*. Learning and experimentation require flexible measures and management processes which address the temporal scales in an integrative way (*integration of temporal scales*). This need for *flexibility* has provided incentives to consider soft engineering strategies particularly in managing fluvial flooding resulting in a new paradigm '*space for rivers'*, as they can be more readily implemented with inherent flexibility. The *integration of temporal scales* also enables the linking of short-term decisions in the broad fields of water, land use and spatial planning to long-term issues in the specific fields of water safety and the freshwater supply and allowing to switch from strategies through *Adaptation Tipping Points (ATP) and adaptation pathways* of the Delta Program. It also allows to inter-linking various investment agendas and looking for opportunities for mainstreaming with planned investments which are also typical features of the Delta Program. Both trajectories require to involve multiple stakeholders in joint decision making process to enhance legitimacy and feasibility and confluence at the enabling element *participatory decision making*.

Above, it is illustrated how Room for the River has contributed to the adoption of ADM in the Delta Program. However, it should be noted that the application of ADM in the Delta Program also had its limitations. For example, the application of ADM in the city of Dordrecht has showed that it involves a time-consuming process requiring a detailed of knowledge of the flood risk management system (Gersonius et al., xxxx). Moreover, an evaluation of the application of ADM during the design and implementation of measures of the Delta Program reveals several methodological and practical limitations for the application of Adaptation Tipping Points and adaptation pathways

[2] WV21 (Waterveiligheid 21e eeuw (2008))
[3] VNK (Veiligheid Nederland in Kaart (2005))

(Rijke, 2014). For example, it appears particularly difficult to apply the Adaptation Tipping Point approach to river flooding and pluvial flooding. And with regard to adaptation pathways it will be challenging from a political point of view to keep options open for future measures.

7. Conclusions

The Room for the River program has shown how effective multi-level governance can be, what its added value can be in terms of broadening societal support for measures and in terms of tailoring water safety measures to meet ambitions in other fields than just water safety. The Delta Program took that approach on board. Specific types of intervention chosen in the Room for the River program, such as by-passes, also found their way into the Delta Program.

On the basis of the analysis presented in this paper it is postulated that Room for the River can be considered a stepping stone in ADM of the Delta Program as it has become the new standard for flood risk management in the Netherlands to take a system approach, involve multiple stakeholders and embrace experimentation and learning. These enabling factors of Adaptive Management (AM), which have been fundamental for the development and implementation of Room for the River, also have influenced and shaped the institutional processes and practices on which the Delta Program is founded and new concepts and approaches could emerge (c.q. multi-layer safety, ATP/adaptation pathways). In retrospect, the Room for the River Program has significantly impacted the transition towards an integrative flood risk management strategy in the Netherlands. Taking a long-term view and acknowledging uncertainties associated with climate change and socio-economic developments, which have been implicitly acknowledged by the Room for the River Program, have also contributed to this paradigm shift.

Upon reflection on the theory on AM, it can be noted that the transition towards adaptive delta management in the Netherlands is taking place through the planning and realization activities in subsequent programs. Whilst two trajectories have been identified that make it probable to assume that Room for the River has been a stepping stone in ADM in the Netherlands, it remains difficult to construct binding proof for this statement. Hence, it can be concluded from the case of adaptive delta management in the Netherlands that the uptake of AM is not always as formally and systematically organized on a program-overarching level as the theory sometimes suggests (e.g. Bunnell et al., 2007; MacDonald et al., 1999; Walters, 1997).

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