Hydrosystems as Multipractice Phenomena
A Normative Approach to Analysing Governance System Failures

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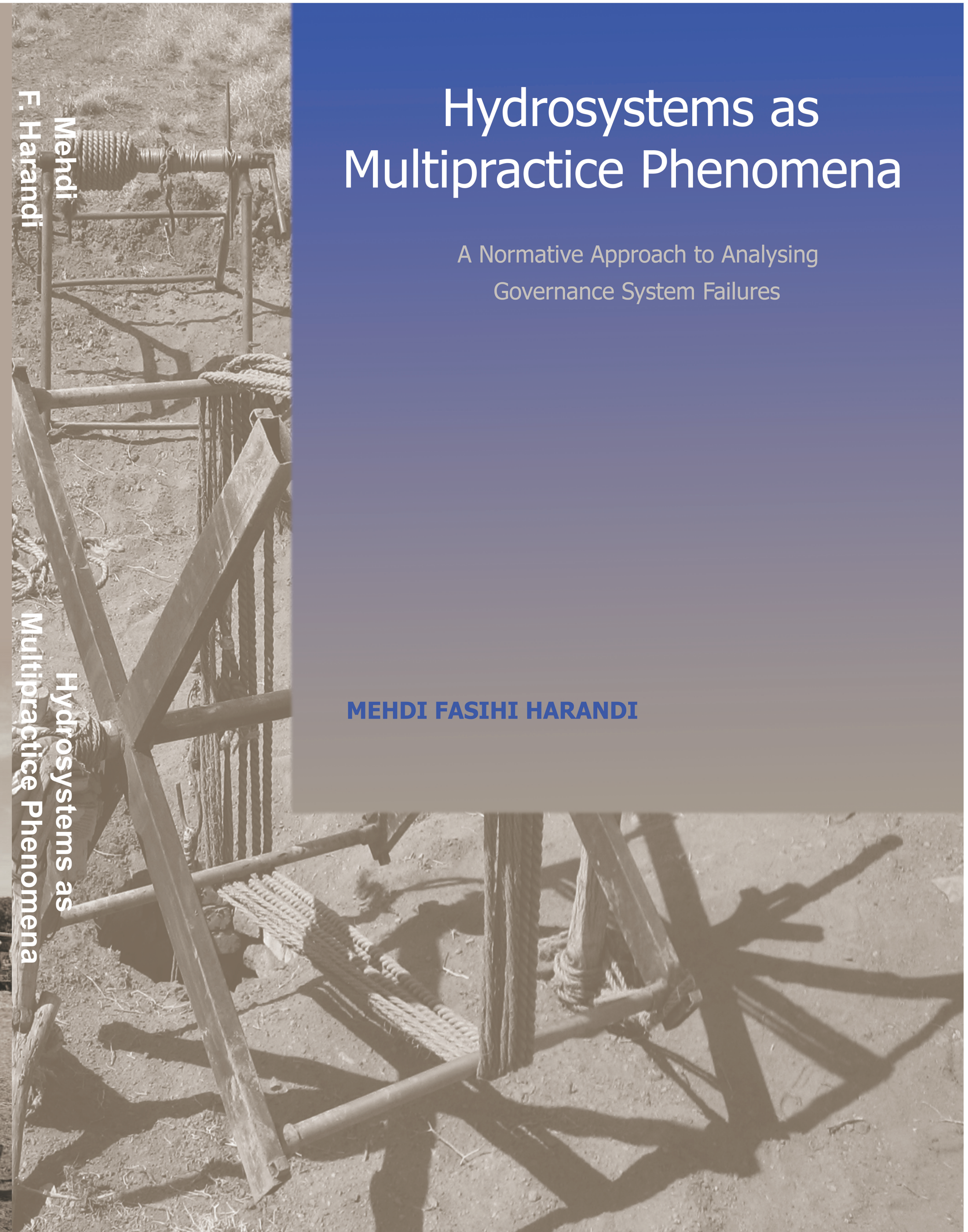
Given the water governance regime, how potent is the normative practice idea in the case of hydrosystems management? How can the normative practice framework explain the failure of the water governance of the Zayandehrud, and how can this explanation improve water governance both in this case and more generally?

Can the governance of the Zayandehrud be understood as a normative practice? If so, how can the distribution of responsibilities, interests and norms, as analysed by the normative practice framework, be seen as a cause of the conflicts that have arisen in the water governance of this river? How are different ways of thinking in the Zayandehrud case (re)shaping the distribution of responsibilities, interests and norms that are causing ‵the conflict within a water-management ‘practice?

Mehdi F. Harandi

Hydrosystems as Multipractice Phenomena



Hydrosystems as Multipractice Phenomena

A Normative Approach to Analysing Governance System Failures

MEHDI FASIHI HARANDI

Invitation to the public PhD defence ceremony

9th of June 2016

Mehdi Fasihi Harandi

Hyrosystems
as
Multipractice Phenomena
A Normative Approach
to
Analysing Governance
System Failures

Brief presentation on the topic

in Senaatszaal, Aula 09:30
Mekelweg 5, 2628CC
Delft

Official defence ceremony
in Senaatszaal, Aula 10:00

Hydrosystems as Multipractice Phenomena,

A Normative Approach to Analysing Governance System Failures

Mehdi Fasihi Harandi

**Hydrosystems as Multipractice Phenomena,
A Normative Approach to Analysing Governance System Failures**

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ter verkrijging van de graad van doctor aan de Technische Universiteit Delft, op gezag van de Rector Magnificus Prof.ir. K.C.A.M. Luyben, voorzitter van het College voor Promoties,
in het openbaar te verdedigen 09 juni 2016 om 10:00 uur

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in memory of my mother, Ashraf, and dedicated to my father, Abbas, to Sepideh without whose love and encouragement this research – and much else – would never have been started.

Foreword

In this thesis, I will attempt to tell a story while also shedding light on a realm we, engineers know little about in engineering science: normativity. I hope to convince readers that we, particularly engineers must deal differently with water, using unconventional models, and to realise that in fact, solely engineering-based solutions simply do not work. For some (civil) engineers, this may still be a new idea. But people in policy analysis who work on water governance have known it for twenty years, and they are developing new frameworks in light of this fact. The topic of the thesis will resonate with any dissatisfied engineer, or indeed with anyone who is not sure what the value of water is. When I began planning this thesis, my sense was that it would chronicle a period of my own experiences as an consultant engineer, but it ended up being much more than that; it lent me insight into my own nature and my own attempts to understand the roles of technology, hubris and engineering derring-do in the current practices of water engineering and management.

I returned to scholastic practices after a sixteen-year gap. I quit my consulting job to acquire a PhD because I realized just how incomplete my technologist view of water was. Therefore, I delved deeper into the issues. I veered into areas I had not anticipated, and so I began to ask whether I could use ethics and philosophy of technology as interpretive frameworks rather than sitting at the computer doing modelling. I now understand how to recognise the societal-related norms' influences on analysis itself — to see the reciprocal values of society and water, the ways in which implicit power relations are expressed in water — and how those may shape a co-operation or a conflict. In other words, this thesis represents my attempt to show *how an engineer can become a socio-technical analyst* and lend renewed assertiveness to actors (that are now technologically engineered).

Important influences on this thesis include *An Evolutionary Theory of Economic Change* (Nelson 1982), *Reflection on Water: New Approaches to Transboundary Conflicts and Cooperation* (Blater et al. 2001), *Blue Revolution: Integrated Land and Water Resources Management* (Calder 2005), *Governing Water: The Ecology of Human Rights: Anti-Dam Activism and Watershed Democracy* (Conca 2005), *Water, Place and Equity* (Whitely et al. 2008), *The Evolution of Water Resource Planning* (Russell et al. 2009), *What Is Water? The History of a Modern Abstraction* (Linton 2010) and *Water Diplomacy* (Islam and Susskind 2013).

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Chapter 3

Harandi, M. F., De Vries, M. J., 2014. An Appraisal of Qualifying Role of Hydraulic Heritage Systems; A Case Study of Qanat in the Central Iran. Journal of Water Science and Technology: *IWA Water science and Technology: Water Supply Journal* **14**(6): 1124-1132.

Chapter 4

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CHAPTER 1

Introduction

Iran is blessed with an abundance of earth and sun but cursed with a scarcity of life's most fundamental need, water.[1] The *Zayandehrud*[2] is the main source of verdure and fertility of Iran's central and Isfahan City. Throughout history the city's progress has been prompted by and depended on the river. Like in many other civilizations, the history of the *Zayandehrud* has shown how people with different interests, beliefs and norms can come together around a river (Hossaini 2006). However, for more than six decades the river has increasingly been facing changing and inconsistent policies. The creation of a joint electricity-irrigation scheme was the absolute consequence and focal symbol of the modernization of Iran. 'This craving for modernity and gigantism [depicted projects like in *Sefidrud* 1962, *Dez* 1963, *Chadegan* 1969 reservoirs etc.] was accompanied, or fuelled, by a vibrant ideology of domination of nature which has its roots in the enlightenment and in 19th century scientism, and blossomed during the 1930–70 period' (Molle 2008). The abstraction of and supply to the gigantic steel factories, refinery and power plants, as well as projects for trans-basin water conveyance and flooding newly reclaimed areas with new canals, have all been developed under such beliefs. The idea then was (and evidence suggests still) that the waters flowing to sea (for Iran for example, the Persian Gulf) are wasted and should be dammed so they can be used more efficiently. The agents of such an idea maintain that infrastructures should be laid out on rivers and valleys to capture as much water as possible[3].

From the 1980s onwards, in Iran there was an era of food security and self-sufficiency policies. The new agri-business and industrial communities 'run' on the

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[1] Worster (1985) describes the American West in similar terms.

[2] Zāyandé-Rūd or Zāyanderūd, also spelled Zayandeh-Rood or Zayanderood.

[3] I explain the idea of hydraulic mission in Chapter 4.

river. Like the earlier decades, the inter-basin water transfers were planned to or from the *Zayandehrud* from or to the remote areas by this means. However, each of them has only slightly solved the (man-made) water scarcities as demands have been increasing in parallel with added water supply. The first anxiety was sounded early in the 1990s, when the water rights of the basin's terminal wetland were pared down. Arid conditions have continued since, leaving the main reservoir at record lows where the downstream users (albeit not the industries) have been announcing severe limits on usage for several years. Their 'Hobson's choice' was to rush into underground aquifers. The river has been witnessing an unprecedented pressure on the water resource ending up with a dried river. In the race between supply and use, there are routine terms that researchers have recently used to argue about such as *conflagration*, 'socio-ecological breakdown' (Molle and Mamanpoush 2012) and 'vulnerability and damage' (Safaei et al. 2013). Billib et al. (2009) note the complexity of our case study to reason why such a deplorable situation has happened: 'the *Zayandehrud* River Basin is an example of a complicated watershed system where the lack of complete knowledge about all the interacting sub-systems has led to failure of the policy makers in addressing the water shortage in the basin'.

The case is also of importance from a socio-technical point of view. It is a classic and well-known example: most of the people, demand and infrastructure are in one and the water resources are in another jurisdiction. After countless false starts and decades of problematic efforts, the *Zayandehrud* hydrosystem's conflicts appear to be reaching a climax. It is now suffering from growing flagrant and deleterious types of tensions concerning the river rights between provinces, farmers and cities, and so forth.

The events outlined above show how complex and intractable the Zayandehrud problem is. As with many other shared rivers, in the Zayandehrud policy-makers also see the use of water as a means to help the state achieve its political goals. That is why societal, natural and political problems are juxtaposed amid the sublime beauty that surrounds the river. Many articles, news items, and stories about problems plaguing the Zayandehrud's resource management regime have appeared recently. In fact, a Google Scholar search for 'Zayandehrud' reveals that more than three hundred scientific articles been published on the topic since 2011. And many scholars have been investigating the river governance system. These articles touch on quite a few cases that involve the same sort of societal suffering described above. They argued many factors have led to over-regulation, over-allocation, tapered groundwater recharging and climbing unemployment, all exacerbated by the irresponsible use of economic tools and engineering approaches. We see the state has governed and engineered the rerouting of surface water and has extracted underground water from the river basin. Aridity has reached alarming levels and become a pressing problem, to the extent that water-related conflicts are systematically reviewed by the government though by the ministerial levels over periods of time. When it comes to aridity, some officials 'have tended to blame the weather—droughts and rising temperatures. But others concede that policy has had a major impact' (Stone, 2015), along with climate change.

The river decision-makers have yet to find a long-term solution or escape *outdated assumptions*. Recently, however, there have been attempts in this direction. An example is the 'IWRM[4] Zayandehrud' project that started in 2010 and

[4] Integrated Water Resources Management.

will last until 2019. It will be implemented in two phases and through different sub-projects. This German-Iranian cooperation aims 'for [the] development of a sustainable water sector for the Zayandeh Rud catchment in Central Iran' (IWRM Zayandehrud, 2015).

1.1. Aims of the thesis

Here, the next sections of this chapter and in the coming chapters, it will become evident that existing approaches to water management and conflict resolution for the Zayandehrud are ill-conceived. The primary aim of this thesis is to analyse the causes of the problems plaguing the Zayandehrud. In particular, I will argue that these problems require more than technical, engineering or managerial measures; we also need to pay attention to their normative or ethical dimensions. In order to do so, I will use both the normative (practice) approach (developed by Hoogland and Jochemsen [2000], Van Burken and De Vries [2012], Jochemsen [2013] and Harandi et al. [2015]) and some more general methodologies from ethics. I will briefly describe how moving away from normative approaches can undermine the holistic thinking and attitudes that were applied in the past.

The thesis' responses and main arguments revolve around questions relating to Zayandehrud governance, along with the challenges these questions pose for appropriately dealing with natural and societal systems. Therefore, the arguments can be divided into two main parts. First, I present a perspective on the approaches that have been used for resolving this river's water problems. In fact, the case of the Zayandehrud reveals what water management and engineering are lacking (as I will soon show). Second, I discuss ethical challenges that arise from the fact that we currently have little prediction skill and/or little knowledge concerning:

- the future course of the drought and the long-term fate of the river (this I will call the analytical gap),

- a network of actors that apply in the water field, which would elucidate (for example) how political forces interfere with other actors' tasks, and

- a normative outlook on governance regimes and on engineering's utilitarian functions (past and present) in the Zayandehrud.

In this chapter, I challenge the conventional water governance approaches that are presented below. Then I explain why a merely technical (engineering) approach is not enough for resolving current water conflicts. However, I demonstrate that a managerial approach is also not enough, and I briefly discuss the IWRM project as an example. Although the so-called negotiated approach fares better in several respects, it may still fail if it does not account for issues of normativity and value.

1.2. Challenging conventional water governance regime(s)

A vital question is whether (and how) we can identify, simplify and resolve some of the convoluted causes of the problems associated with the Zayandehrud. But first I will analyse the prevailing water governance approaches, in order to clarify what my thesis adds to the current literature. I will argue that we need to move beyond current water management regimes to deal with these problems, and that we need to include normative issues as well.

1.2.1 Existing literature

A literature review reveals that the field of water governance comprises many different subfields, such as boundary issues and multi-level (societal) challenges (e.g. Ostrom, 1990; Pahl-Wostl et al., 2007; Pahl-Wostl, 2009), geo-political issues (e.g. Molle, 2009; Biswas, 2011; Gupta et al., 2013; Warner et al., 2013), socio-technical and political issues (e.g. Swyngedouw, 2009; Dellapenna and Gupta, 2009;

Islam and Susskind, 2013) and ethical issues (Doorn, 2014; Harandi et al., 2015; Grunwald, 2016). Gupta and Lebel (2010) have developed an allocation framework for water sharing, and they believe that the following factors are among the causes of insecure access to water:

- institutional and territorial fragmentation
- poorly managed multi-level governance and conflicting governance patterns
- limited capacity at the local level
- unclear allocation of roles and responsibilities
- questionable resource allocation

The case story events showed (and other chapters also indicate that) almost all the aforementioned factors are seen in the river, and are the indications of managerial credibility and gaps in the Zayandehrud governance system. Relatedly, a literature review shows that conflicting interests and values (e.g. Warner et al., 2013; Harandi et al., 2015; Ravesteijn and Kroesen, 2015), complexity and uncertainty in the societal, natural and political domains (Islam and Susskind, 2012), and risks are the provocative water-related issues that cross established institutional boundaries and involve multiple stakeholders.

The Zayandehrud is also a socio-technical structure that inherently provokes conflict when it encounters natural and engineering systems (e.g. Molle and Mamanpoush, 2012; Daneshmand et al., 2014). Therefore, what emerges from the extant scholarship is the need to enrich current management patterns within water governance systems in the realm of conflict resolution and decision-making. Pahl-Wostl (2009) has identified the key elements of water governance as:

- institutions—formal and informal;

- actor groups, including state and non-state actors;
- multi-level interactions of governance patterns (i.e. inclusive, discursive, or deliberative governance);
- governance modes—bureaucratic hierarchies;
- markets;
- networks.

Ravesteijn and Kroesen (2015) emphasize that water problems are divided into three interlinked categories: technical, managerial and social-interest-related. In turn, they relate these categories to three aligned approaches that have each helped to resolve water problems: technical-economic, integrated and negotiated. '[C]onflicting interests and values are reconciled and managed in different ways through these approaches' (Ibid. 851), which makes them important for my project. I will use these categories – illustrated in Table 1 below – as lenses that clarify the original contributions of my thesis.

Table 1: Water problem categories and the solution approaches

Water problems	**Problem-solving approach**
Model-based	Technical-economic (e.g. cost-benefit analysis, stochastic and probabilistic and game theory and computer and optimization simulation modeling that use the river basin as a boundary condition)
Managerial	Integrated (e.g. system engineering linked to IWRM paradigm)
Social-interest-related	Negotiated (e.g. **w**ater **d**iplomacy **f**ramework [WDF] proposed by Islam and Susskind)

I will argue that technical and managerial approaches fall short and that we must consider social interests and values in the case of the Zayandehrud.

1.2.2 Why model-based approaches fall short

Does it make sense that water managers overwhelmingly rely on models __coming from modes of computer simulation modeling (Landström and Whatmore 2014)__ to conceptualize hydrosystems mathematically? For some time, cutting-edge problem-solving approaches have been seen as merely technical and have faltered in the realm of decision-making. Gleick (1998) provides compelling evidence for this; indeed, when he wrote his paper, water was already in crisis. He suggests that a new approach to long-term water planning and management is essential to escape the water crisis. His often-cited paper shows that even at the turn of the millennium, scholars recognized that approaches to developing plans could not be strictly technical. True, projects that combine technical and managerial approaches often supply huge and growing populations with basic water needs. However, Gleick criticises the symbols of hydrocracy, artificial reservoirs. They were built to manufacture more water for parched lands, but they also cause people to compete for and struggle over water. This is where an integration paradigm for these complicated human-made problems applies. Water management creates obstacles to the integration of natural, societal and political systems if in modelling, scientists and engineers still wish to rely on boundary conditions, 'conduct controlled experiments, and measure results' (Islam and Susskind, 2013: 7). Pahl-Wostl (2015: 184) has acknowledged that research on resource governance, in general, has been facing an 'absence of a minimum set of shared standards for conceptualizing variables and conducting data analysis.' Therefore, when variables are not narrowed enough, the imaginary model falls short, and will cause water governance systems to fail – or, at least, 'will not lead to clear cut solution' [sic] (Islam and Susskind, 2013:14).

A lack of analytical tools as decision support systems (DSS) has been acknowledged by the IWRM Zayandehrud Project. According to the project's website, it is seeking 'a data-based tool for the quantitative simulation of the water resources' (IWRM *Zayandehrud*, 2015) to assess water management decisions and to function as a DSS. However, the project makes an attempt to employ an optimisation model to create a water management model along the river. The second indication of the gap is a paper published by Safavi et al. (2013). It recognises the importance of the DSS in the Zayandehrud for the implementation of IWRM. It opens with a suggestion regarding new support methods as 'possible options to be used in DSS' (I also suggest such methods in Chapter 2, inspired by Harandi et al., 2014) and simultaneously analyses the problems of the current DSS implemented in the Zayandehrud. The third indication of the analytical gaps is referred to in the research of Mehrparvar et al. (2015). The paper loosely bases its analysis on the social dimensions of water problems, and uses game theory to propose a 'social conflict resolution' model for the Zayandehrud water conflicts.

However, the thesis also implements a model-based approach in Chapter 2 to argue that, in the case of the Zayandehrud, model-based approaches do not suffice. We need to propose a more systematic approach (Pahl-Wostl 2015: 184) to analyse the inherent uncertainties of hydrosystems.

1.2.3 Why managerial approaches are insufficient

I will focus on integrated water resources management, which is applied in the current problem-solving strategies in the Zayandehrud. The IWRM paradigm originated in the mid-1990s and is now widely recognized as a response to merely technical approaches. Global Water Partnership has introduced IWRM as a process by which water management can be promoted if its components – land and related resources – are managed for maximising economic and social welfare in an 'equitable manner without compromising the sustainability of vital ecosystems' (GWP 2015). IWRM strategies are based on the following five pillars:

- Resources are finite and eventually come to an end.
- The actors of hydrosystems development should be involved in water management at all levels.
- Women are central actors in the provision and safeguarding of water, as well as in management practices.
- Water has societal value and is a public good.
- And, crucially for this thesis: IWRM should be implemented equitably and efficiently.

A serious constraint that causes IWRM to rely upon technically-oriented models is that, in this paradigm, 'water should be managed in a basin-wide context' (Rahaman and Varis 2005: 15). This physical boundary 'does not sufficiently recognize the existence of the multiple geographies — political, socioeconomic, cultural — of socio-ecological systems' (Del Moral et al. [2014: 24]).

To see what the real gaps are, I return to Islam and Susskind (2013), and to the notion of *complex* water problems and the network thinking approach. While these are a source of IWRM's confusions, they reveal water management as a complex world. In their book *Water Diplomacy*, Islam and Susskind describe the ways in which problem-solving in water management shifts from technically-oriented approaches to societally-oriented approaches. They illustrate this with a historical timeline, starting with the UN-sponsored water conference in 1977 as the node that gave global recognition to these 'interlocking problems and changes.' Regarding IWRM, they identify system engineering – in which one seeks to (re)connect system components with their dynamics – as central to the practice of IWRM. But IWRM often demonstrates unorthodox tactics. Again, a system engineering approach works well when 'the cause-effect dynamics involved are well understood, and may not provide much insight when its boundaries are ill-defined' (Islam and Susskind 2013: 9).

1.2.4 Negotiated approach important but still lacking

It is now quite clear that water management requires stakeholders to engage in dialogue, coordination and cooperation. This kind of tactic is what Ravesteijn and Kroesen (2015) call a negotiated approach. A similar perspective, called the Water Diplomacy Framework, has already been developed by Islam and Susskind (2013). Both versions reject the current pattern of negotiations over water, in which the parties try to adjust a win-lose discursive framework to maximise their own benefits. Therefore, negotiation over the values and interests of the involved actors is crucial in order to ease the problems around water. The more interests are represented, the more issues are at stake (Coughlin 1999) and the more complexity must be managed. Therefore, we need to scrutinize the norms and values behind these actors' interests if we wish to manage conflicts and reach normative decisions.

We cannot analyse or resolve all water problems with one standardized approach. Like many general concepts such as sustainability (for which the *telos* may never be fully fulfilled), these approaches still face some institutional barriers and definitional confusion (after Safavi et al. 2013 and Grigg 2008). This thesis will seek to improve approaches in which Ravesteijn and Kroesen (2015), as well as Islam and Susskind (2013), have found flaws. Using normative practice theory, it will reduce the gaps between the boundaries mentioned in the prior section by interpreting the ways in which actors' values (and/or interests) conflict to each other.

1.3. Normative approach 'the next best thing'

Of the five pillars of IWRM, the two that can be linked to normative concerns are: 'water is a public good and has a social and economic value in all its competing uses, and IWRM is based on the equitable and efficient management and sustainable use of water' (Engle et al. 2011: Table 1). Water management is constantly called on to enforce these pillars. What deserves attention is the notion of *good* water governance, which is a *normative* notion that cannot be understood in technical or managerial terms, or even in terms of negotiation.

1.3.1. Good water governance as normative notion

The Zayandehrud water conflict has surfaced in different forms: between today's generation and future generations that might face water scarcity, between upstream and downstream people, and among diverse types of actors (cities, farms, industries, etc.). We cannot identify ethics as a solution for water-related conflicts and then force the practitioners to agree to take action. Rather, ethical frameworks can bring in a better understanding of 'the normative structure of water conflicts and support deliberation about responsible solutions' (Grunwald 2015: 27).

Rather than expounding on ethics in general, I will explain why good water governance is a normative notion. It requires (see Ostrom et al. [1994], Ostrom and Ostrom [1977] and Gupta and Lebel [2010]):

- Not merely viewing water as a resource,
- attention to water as a common pool resource, and
- attention to the value of equity in water governance.

Doorn (forthcoming) uses the OECD (2011) to characterize good water governance. It should involve:

- Legitimacy in complying with international and European Union requirements;
- subsidiarity in performing tasks allocated in the framework of a decentralized unitary state;
- effectiveness in delivering policy outcomes in a transparent way and achieving expected results;
- efficiency in doing it at the least cost;
- equity in ensuring fairness in service delivery and allocation of uses.

A notion such as equity in water governance makes the discipline of ethics relevant to these discussions. Ethics seeks ‘an argument-based and peaceful way of conflict solving – [that] is built on a strong normative foundation' (Grunwald 2015: 23; from Habermas 1991). For the purposes of my thesis, this foundation connects the practice and the practitioner. Here ethics asks not ‘Where should we go?’ or ‘When should we start,' but rather ‘How should we proceed?’ The Zayandehrud case clearly raises questions of equity. It obliges us to ask *how*, for example, factories are getting more water when downstream rights-holders[5] have gotten no water from the river. Indeed, Yousefi et al. (2014) have indexed eight governance criteria relating to the Zayandehrud, including equity, equal democratic opportunity, efficiency and effectiveness, transparency, and accountability. Regarding equity, this research assessment has revealed that most of the farmers (77%) see no justice in

[5] Here rights-holder refers to any sector (private or public) that has a common, traditional, documented or undocumented allocation of surface or groundwater that comes from a market-base mechanism (private or governmental). Where the Zayandehrud is concerned, there are many different rights-holders: farmers, cities, state agencies, non-agriculture businesses, and environmental groups. But some claim that the agricultural sector offers less productivity and added value than the industrial sector. Therefore, until recently, it often received no priority in the allocation of the limited water supply. There is a huge amount of literature on rights and duties relating to water, much of which exceeds the scope of this project. See, for instance, Sultan and Loftus (2013).

the water allotment regimes or in their implementation, though decision-makers deem them very technical and precise.

I argue that good water governance in the Zayandehrud case requires an ethical framework based on the following goals:

- Challenging views that give rise to the major conflicts in the case: 'water has an economic value in all its competing uses and should be recognised as an economic *good*' (Young et al. 1994).

- Contributing to the conviction that water is a common *good* (McGee 1911:822).

- Strengthening views in water management that consider justice to be the *ultimate goal*, and that subsume related values under this one. This view is presented in Chapter 3, and Chapters 4 and 5 develop it.

1.3.2. Introducing normative practice approach

Biswas (2004) has argued that water-related problems can be resolved only through the proper coordination of multiple institutions and multiple stakeholders. Our case has multiple dimensional, -sectoral, and -regional problems overflowing with competing interests, agendas, and causes. The central issues at stake do not only involve the inadequacy of standard legal, engineering and economic frameworks; they are ethical as well (Blatter et al., 2001). Again, '[e]thics may contribute to a bottom-up process of conflict solving by conducting an ethical discourse with all groups involved – and which advocates for those who cannot participate directly such as future generations or ecosystems' (Grunwald 2015: 27). I argue that the Zayandehrud water management problem is, in fact, a matter of coordinating values among actors (Chapter 4) and among the values that these actors hold dear (Chapter 5).

Providing a conceptual clarification that shows why the values of these actors conflict, is at the heart of my thesis. Normativity relating to rules, and thus to individual and collective professional actions, is shaped in advance because such actions have inherently normative aspects (Jochemsen 1997). According to the normative practice approach, 'normativity' is intrinsic to practices (Van Burken, and De Vries 2012: 137). Recall the introductory chapter; I described the framework of *Normative Practice* as developed by Hoogland and Jochemsen (2000, 2006 and 2013), Van Burken and De Vries (2012). These writers initiated the theory as a response to the difficulties that they, as medical practitioners and military commanders, had been encountering as they translated relevant rules and obligations into research practices. Indeed, a *practice* refers to the intrinsic value of an action and the unique way of having values beside practice. In the theory of Normative Practice, *values* are embedded within *practices* (Fig. 1).

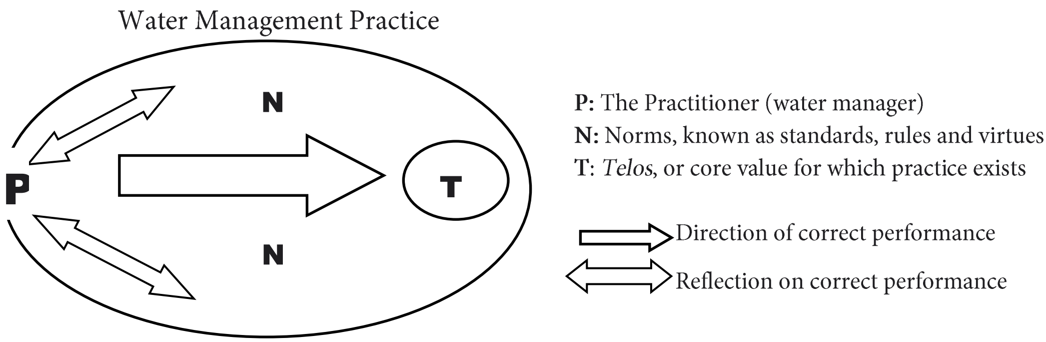

Figure 1: Practice, norms and Telos (Jochemsen 2013)

1.3.3. The Structure of a Normative Practice

As mentioned above, Pahl-Wostl (2009) has developed a framework to interpret 'change in resource governance regimes' by analysing the structural rules of any hypothetical governance regime. In Chapter 4, my thesis augments this framework by elucidating the *directional* rules of a water management system as well as its *structural* rules. Perhaps the most crucial goal in any system analysis is, knowing the *structure* and *direction* of the system at hand – which can respectively reveal the *task* and *interest* of a practice. To address the normative character of practices, we use the concepts of structure and direction as implicit rules. Structure determines responsibility: who is permitted to do what, and how are they permitted to do it? Direction (often linked to *regulative* rules) reveals the deeper values of the practice. Figure 1 shows the direction of correct performance takes a practice to its ultimate goal, or what Aristotle named *Telos* (Finality).

Wescoat (2013: 4759) uses the term *practice* in his paper, and 'assesses changing norms of water use known as the duty of water.' He meticulously defines this concept. Wescoat argues that social values, such as careful management, have been eclipsed by other measures and standards where 'the duty of water' is concerned. Wescoat keeps a close eye on the *normative* dimensions of this definition, and shows that (for example) careful management has 'normative connotations'. He mentions the ordinary practices, standards, values and justifications of these normative connotations.

However, the notion of normative practice can isolate tasks and responsibilities from values to show how every related social activity (each is by definition a practice) can be linked to certain contradictions. Karwat et al. (2015) define engineering as an action (that is, a practice) that should be seen not simply as a client's instrument but instead as an 'engineering Praxis.' With this term (after Riley 2008), which points toward the ways in which engineers affect societies and the world, they connect engineering, communities and normativity. Nelson and Winter (1982) have also stressed cognitive routines that have cued engineers and designers to seek the greatest good for the greatest number and not in others, which represents a change in values. These are such lopsided views that, as Geels (2007) has also pointed out 'this can make them [engineers] blind to developments outside their focus'. My thesis will expand on these ideas in chapters 3 and 4.

Frega (2013) has suggested replacing 'our usual concern with norms and institutions with a broader concern' which in his paper he terms normative orders and *normative practice*. His article devises a case study to explain the 'functioning of normative practices' in a multidisciplinary context (Frega 2013: 17). He outlines a pragmatic approach for widening our understanding of normativity theory. This thesis continues to develop Frega's arguments while also contributing to other related discussions, because it is more important than ever for us to examine the norms, values and responsibilities of actors involved in development processes. Several of the six conceptual traits that Frega associates with practice-based approach are articulated in this thesis: namely, focusing on norms and actions, defining normative practice through structural and directional norms, and taking an empirical approach.

As in many other *networks*, river stakeholders are embedded in a complex web of actors who interact 'at various levels and in various ways, contribute to policies and the decisions of the organization [so] it is difficult to ascribe moral responsibility for the organization's conduct' (Doorn and Van de Poel 2012). Having a map of the actor network and understanding how the values interact are two minimum requirements if we wish to analyse such a complex situation. Therefore, I incorporate an interactive analysis on the involved actors of the river and normative practice theory to reveal how (re)framing duties and responsibilities can be shaped in the Zayandehrud (Chapter 5).

1.4. Research questions

In this thesis, I present a major problem statement, as well as four sub-statements to which the chapters provide answers. My research illuminates the desires, roles, rules and interconnections associated with the actors who are involved in hydrosystems development. What will happen if we aspire to adjust the socially-constructed values of actors who are involved in such technological actions (Holt 2001)? It is crucial to identify normative principles that can reform the actors' values and norms during hydrosystem development. This will involve a framework of complementary notions about what a river is, such as 'a gift from nature,' 'a focal point for community building,' and 'understanding water as an entity,' that connect water to the societal and cultural environment. Water, it turns out, has something genuinely new to teach philosophy.

I am primarily interested in analysing what has gone wrong in the Zayandehrud case study, and secondarily interested in explaining how the governance of this river can be improved. My research questions will ask exactly what we mean by 'governance gaps' – and how such gaps are related to the normative dimensions of this practice (for water managers, for engineers, and so on).

My central questions are practical ones that call for answers from several different disciplines.

Given the water governance regime, how potent is the normative practice idea in the case of hydrosystems management? How can the normative practice framework explain the failure of the water governance of the Zayandehrud, and how can this explanation improve water governance both in this case and more generally?

To reduce conflict and streamline decision-making in the case of the Zayandehrud, there have been growing calls for actors to re-think how they engage in processes. To what degrees do the proposed support method (Chapter Two), backward-looking engineering (Chapter Three) and normative practice framework (Chapters Four and Five) enhance or impede these calls? The thesis uses tools from philosophy to achieve a new perspective on and generate new insights about these problems. In doing that, the research proposes four reasons and related analysis methods for discovering the causes of the current conflicts over water. I argue that there are four possible causes of the conflict, and analyse each of them separately. Here I outline them briefly.

Water governance systems fail and prompted-by-conflict water problems arise:

- when simulation modeling modes are become central of governance systems,
- when rediscovery of the past practices (e.g. water governance) values, and historical inquiry into how water systems have developed are ignored in the name of modern standards,
- when a single actor holds multiple conflicting values, or
- when their different values lead to conflicts among actors.

I will investigate the first cause in Chapter Two, using a technical-analytical method to predict long-term river behaviour.

Sub-question 1: Why can't current decision support systems fully prevent the Zayandehrud from experiencing a socio-ecological breakdown, and what new method(s) can be proposed as a redefined DSS for analysing the river's long-term behaviour?

I answer this question in the second chapter by using a mathematical tool (favoured by modellers) to demonstrate that the dynamic nature of the river's water level provides a straightforward result that can draw a red line for a successful decision-making process. The chapter shows that one approach by itself can neither conserve the river nor deal with the attendant societal issues. The current tools (such as they are) that support decision-making processes in the Zayandehrud cannot conserve water resources; in fact, these models have brought aridity to the river. This indicates that the current water governance patterns in the river are failing.

Sub-question 2: Can the failure in the water governance of the Zayandehrud be explained by the modern approach that neglects lessons from the past and neglects the continuity between old and new water engineering systems, seeing water primarily as a resource?

Here I investigate the possibility that disconnection from history can cause problems. Decision-makers and engineers should not ignore past engineering values that communities still hold dear. In Chapter Three, my project questions the wisdom of utilitarian engineering and explores the dysfunction of recent engineering. The case study described in this chapter proves that the past pragmatic-focused engineering knowledge still deserves to be either the solution or part of the solution to the current water dilemmas. Given current scientific and technical worldview(s) that *overwhelmingly try to dissociate the past from the present*, I urge opinion-makers to re-examine their 'myth of progress' (Zarandi 2003). Using Qanat as a case study raises questions about the overlooked functions of hydraulic heritage. I argue that thanks to their 'qualifying role,' Qanats should be taken into account during development in the Zayandehrud basin. This chapter reveals the problems that modern thinking – specifically, seeing water as a possession – has created for the Zayandehrud. Via the notion of the qualifying role, I gradually relate the discussion to the new domain of normative practice, but without explicitly mentioning this concept. Normative practice teaches us what the qualifying rules (not the roles) are. Therefore, this chapter prepares the reader (especially supposing that s(he) is a utilitarian engineer and not very familiar with philosophy!) to leave the purely technically-oriented realm behind.

Sub-question 3: Can the governance of the Zayandehrud be understood as a normative practice? If so, how can the distribution of responsibilities, interests and norms, as analysed by the normative practice framework, be seen as a cause of the conflicts that have arisen in the water governance of this river? How are different ways of thinking in the Zayandehrud case (re)shaping the distribution of responsibilities, interests and norms that are causing the conflict within a water-management 'practice'?

This third sub-question introduces the practice-focused perspective to address the role of a transdisciplinary vision in the water governance debates; it uses ethical theory (specifically, normativity theory) to consider the possible tensions and conflicts experienced by the *Mirab* (the traditional name for a water manager in old Persia) as a social activity. The fourth chapter also assesses the weaknesses of the river's current water governance regime. I shed fresh light on water management by comparing old and new governance systems.

Rather than focusing chiefly on the challenges themselves, I seek to analyse the normative dimension of water-related practices – a dimension that, because it is currently not fully acknowledged, creates serious challenges due to conflicting values over water usage. In doing so, I develop a new framework based on the results of the case study.

Sub-question 4: How do the structural and directional norms of actors in the Zayandehrud development processes clash with one another, and how do they intensify conflicts? Who is responsible for this deadlock?

The fourth sub-question focuses on conflict(ing values) *among* actors of the governance system. Many scholars, and the chapter as well suggest using *systematic network analysis* instead of *system analysis*; I follow this suggestion in Chapter Five, as I mentioned earlier by incorporating an interactive actor analysis and normative practice theory. I use actor or stakeholder[6] analysis to determine which systemic measures, acts and actors are involved in the case. What would happen in the absence of actor or stakeholder analysis? Based on the work of Chambers (1994; 1997), Reed et al., (2009) argue that in the absence of stakeholder analysis, marginalized groups can be misled by powerful actors for example in the decision-making processes. They show that by means of the stakeholder analysis we can identify the key elements of actor networks, and to assess 'individuals, groups and organizations affect or are affected' (Tehrani and Harandi, forthcoming). They argue, following (Grimble, R., Wellard, K., 1997), that conflicting values and the relations between stakeholders are well-defined by actor or stakeholder analysis. Therefore such analysis can facilitate planning a constructive approach to the participation in social learning, 'and negotiating to reach consensus' (Tehrani and Harandi, forthcoming). 'Also there is potential to bias results and jeopardize long-term viability and support in any participatory exercise, (Reed et al. 2009). Finally,

[6] Freeman (1984 and 2010) has identified stakeholders as groups or individuals 'who can affect or are affected' by organizational objectives (consider policies, decisions or actions) of systems. Therefore, stakeholders are in and/or related to the system. They do not directly behave with the system. Actors in fact are always stakeholders but the reverse is not necessarily true. Here and throughout this chapter, we take them as a synonym of 'actor'.

the capacity of different stakeholders to participate in the process and appropriate type of participation by different stakeholders and analyse their priority is assessed.' (Tehrani and Harandi, forthcoming)

Why is the primary analysis in this chapter important? The actor analysis illustrates the nodes at which interests are interlocked, and then shows the friction points among actors in the case. This highlights the roots of the conflicts in these areas.

The chapter once again applies a normative practice framework to reveal (for example) how governance can be excessively patronizing and how *structural* and *directional* norms interact. Direction and structure are more precisely introduced in Chapter Four. But for example, consider a factory with a division that has as its ultimate goal the production of environmentally friendly products. This is the direction of a normative practice. In doing so, the factory should create a division for controlling the amounts of pollutants, etc. This has to do with structure. I will argue that a normative practice works well when its direction and structure fit together well.

The purpose of my thesis is to provide evidence that these *four causes*, each of which is studied in a separate sub-question, exist and can explain troublesome situations. Of course, my findings will not apply to every situation. And it is quite possible that there are additional causes for the governance system failure and conflict that are not evident in my chosen case study. However, I do show that these four possible causes need to be investigated when problematic situations arise. I conclude by arguing that they are often generalizable to other cases. Again, though, for each situation other possible causes need to be investigated as well; my conclusion briefly considers other causes, based partially on the literature, partially on personal experience, and partially on informed speculation.

The conditions and actions that led to the Zayandehrud problem are not unique or isolated. Indeed, they are prevalent. This situation is similar in many ways to the California central valley (i.e. over-allocation on a smaller scale in the Colorado River) and to the Murray-Darling basin in Australia (i.e. huge groundwater depletion and a millennium drought). Thus, apart from a few exceptions in my final chapter, methodologically no effort has been made to compare the Zayandehrud case with other case studies. In the case study method, a case is studied as such and not compared with other cases, as this would require equal amounts of empirical data to be gathered for all the related cases.

However, in the final chapter, I will tie up these discussions by arguing that lack of attention to interests and norms, as a result of uncoordinated and unchecked decisions linked to water, is an inevitable legacy of our current governance patterns. I will show that it is time to re-invent these patterns via several ethical enquiries.

The thesis will make some speculations regarding the generalizability of arguments relating to other cases, and will make five recommendations for future research.

1.5. 'What is the *explicit methodology?'*

An important part of the thesis' methodology is comparative historical analysis especially in Chapter 3 and 4. However, I do recognize such a comparison as a potential key element of the thesis. I am aware that, basically historical analysis is difficult and some scholars miss a clear design of the comparison, both in terms of internal consistency and emerging realities.

In terms of internal consistency it might be not quite clear that whether the material that the research uses allows the comparison to be shaped well. For example, on the old Mirab institution I focused on the past according to Sheikh-Bahai scroll - a 400-year-old ancient document of the water sharing of the *Zayandeh-Rud*– and Mahmoudin (1969). I have worked off the formal documents for the old practice. But descriptions on the Mirab Company are based on board contemporary evaluations in water allocation, plus a certain set of documents (i.e. the contracts and the company chart or the contract with ERWB). I show how difficult the comparison is, and how the comparison should be ideally performed, and why the thesis has not been able to completely follow the ideal comparison.

1.6. Overview of chapters

One might question how Chapter Two, because it deals with an issue of uncertainty, will contribute to philosophy of technology. However, the chapter is positioned well to 'improve the management of uncertainties in water management practice' (Isendahl et al. 2010). Uncertainty is defined differently in different disciplines, from epistemology to statistics, but 'in philosophy, it is time we learn the value of a low and stable degree of uncertainty' (Floridi 2015_b). Doorn and Van de Poel (2012) assert that engineering and technology development are complex processes that are characterised by three characteristics, including uncertainty. In water management, scholars such as Pahl-Wostl and Gupta have viewed practice-related uncertainties from four perspectives: positioning, urgency, responsibility and trustworthiness.

Chapter Three elucidates another cause of water problems; it illustrates the qualifying role of hydraulic heritages by addressing the skills associated with their governance, planning and construction. Firstly, it addresses a tradition that engineers know little about. It asks how a return to the values of hydraulic heritage, with its inclusion of technical norms, can be used in a technical-economic approach to water problem-solving (Table 1). How can we learn from the past processes mentioned by Pahl-Wostl (2009): 'dynamics of governance regimes as learning processes'? In fact, the chapter triggers 'a debate about what the knowledge and skill requirements are for the water professional of tomorrow, and who these professionals will be' (van Vuren et al., 2009). Secondly, it introduces historical rights linked to hydrosystems that draw attention to the issue of engineering responsibility in water governance *systems* as 'an ensemble of elements performing the function of governance in a given setting' (Young, 2013). Finally, the chapter reiterates that hydraulic heritages are impressive technical and engineering feats (that is, it uses an integrated problem-solving approach).

Chapters Two and Three hint at the importance of technical (it was also named, model-based) approach values, though they offer relevant criticisms as well. But Chapters Four and Five gradually move away from technical argumentation and toward normative argumentation. They focus on two other possible causes of conflict. These chapters extend research discussions into topics surrounding practice, norms and normativity; they also illustrate normative practice as a theoretical framework for philosophy of technology. They analyse the causes of water conflicts in terms of values and responsibilities, in order to illustrate how values (as in the water apportionment mechanisms in the Zayandehrud) are being reshaped. When a conflict arises, the first concern is to deal with the actors involved in it and with the mistakes these actors have made at different levels. Actor or stakeholder analysis is well known and there is no need to describe it in detail, although I give some background on it in Chapter Five. Again, though, I should stress that I investigate the possibility of tension within one actor (in Chapter Four) and among actors (in Chapter Five). Chapter Four shows if certain responsibilities decline or alter, it would change the relevant objectives of hypothetical practices and lead to contradiction. Therefore, I elucidate issues surrounding the interlocking relations of a water governance system. I examine, roles, rules, responsibilities, interests, relations (particularly in Chapter Five), and the ultimate purposes of actor(s) – especially in water apportionment and its mechanisms (Chapter Four) – in order to propose the idea of normative practice.

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A raindrop can fall into the mouth of a seashell to turn into a pearl or the mouth of a snake to turn into poison.

– Imam Ali (AS)

CHAPTER 2

The Dichotomous Markov Process with Nonparametric Test Application; a Decision Support Method in Long-term River Behavioural Analysis: The Zayandehrud River; a Case Study from Central Iran[7]

[7]As the main author, I have already published a version of this chapter as Harandi, M. F., Yarahmadian, S., Sepehrifar, M., and Van Gelder, P., 2014. The dichotomous Markov process with nonparametric test application; a decision support method in long-term river behavioural analysis: the *Zayandehrud* River; a case study from central Iran, in: *Stochastic Environmental Research and Risk Assessment.* **28**(7): 1889-1896. doi: 10.1007/s00477-014-0854-y.

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Index Terms—*Zayandehrud River, DMN, Real-time River Management, Extreme events modelling, Nonparametric Test.*

Environmental management and in the current context, specifically rivers, need a set of decision support tools to overcome the inherent uncertainties that appear in the system. These uncertainties, which are the result of the spatial variability of the driving processes, lack of comprehensive knowledge (Pourbakhshian et al., 2011), and/or the structural uncertainties of the system (the hydrodynamic[8], morphodynamic,[9] and ecodynamic[10] elements), should be tackled by decision makers and be supported by different support tools and methods. These uncertainties direct the feature of the models, simulations, and estimations, which are misleading for the decision makers who are struggling i.e. with water allocation issues (Syme, 2013) links to the river discharge.

A real-time decision-making process entails the knowledge of prior and subsequent consequences of the decisions. In this regard, a full understanding of the various systems' components and incorporating their interactions into appropriate methods for structured practical procedures of decision-making are of crucial importance. Indeed, making decisions need Decision Support Systems (DSS) "to support decision making in complex problems by structuring the information and by analysis and evaluation of the effects of different alternatives" (Sprague and Carlson, 1982).

Real-time river management (Wu et al., 2012) is essentially a multifaceted decision making process. In its nature, Real-time river management is connected with hydrologic alterations, which are affected by upstream artificial reservoirs and

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[8] i.e. discharge, water depth/level, flow velocity, turbulence, and inundation frequency.

[9] i.e. erosion, transport, deposition and sorting of sediment, bed forms, channels, bars, and longitudinal profiles.

[10] i.e. physical habitats, effects of flora and fauna such as flow resistance, sediment trapping, and vegetation succession such as colonization, growth, death plant forms, and sorting patterns.

precipitation variability (Zhao et al., 2012). One of the important obligations of river decision-makers in arid regions is to regulate water based on the amounts of water, which should be apportioned to the users, particularly in semi-arid areas such as Iran and in certain seasons. As such, the decisions related to manageable water in the river are fully dependent on this parameter, which in practice is measurable in term of water level in every cross section of the river downstream. Certainly, annual, biannual or even middle-run discharge cannot be a reliable basis for long-run decisions. Theoretically, the output of the decisions related to managing a certain amount of water during yearly timeframes can be depicted as periodic water level data, which show the increasing and decreasing water levels influenced by such decisions. In this context, the important question is to realize how these periodical releases affect the long-term river behaviour.

Stochastic and deterministic models for modelling water level fluctuations are both possible options to be used in DSS. However, because of the intrinsic randomness of the problem in time and space, stochastic models are more appropriate for the particular case of lower level DSS. By employing an appropriate stochastic model, it is possible to foresee the long-term behaviour of the river to a certain extent and also to use the data and statistics for the practical aspect of the problem. It should be added that the stochastic models also have some inevitable complexities and uncertainties, which cause tremendous difficulties for water governors as decision makers.

There have been numerous deterministic and stochastic modelling approaches for water level fluctuations. We would refer the reader to the adaptive network-based fuzzy inference system (Ying and Pan 2008), the fuzzy Multi criteria (Zhang et al. 2009) Bayesian (Reggiani and Weerts 2008) approach to decision-making, Markov Models (Kehagias 2004; Vanem 2011), artificial intelligence (Kisi et al. 2012), and the ANN and ANFIS models (Talebizadeh and Moridnejad 2011; Magny et al. 2011). One of the main difficulties in using these models and their respective software is rooted in the morpho-dynamic upstream and downstream changes of rivers, which requires a continuous calibration of the software used in these methods. In general, the main challenges in river' DSS are related to the fact that the lack of sufficient data complicates projection of long-term trends for long-term plans for rivers. 'While working on prediction of drought and flood years we are always making judgments and decisions on the basis of incomplete information, but this is preferable to decisions based on no information at all' (Panda et al. 1996).

According to (Syme 2013), the scientists' common approach of overcoming uncertainty is by reducing "the information deficit to ensure certainty" to deal with water allocation decision-making issues. Therefore, access to long-term data on streams' steadiness, is in massive demand by decision makers. These data are important for both decisions made for semi-arid area, and also for development of other fundamental features. This chapter aims to introduce a decision-maker-friendly method to deal with complexities and uncertainties stemming from the nature of this problem as well as from common differential equation models (Vanem 2011), which are far from fulfilling decision makers' needs and contributing in the decisions that should be made under intensive extreme environmental events, such as drought (Unami et al. 2010) and floods. The chapter discusses uses nonequilibrium systems driven by Dichotomous Markov Noise (DMN) model, which appears in a wide variety of phenomena in environmental sciences, physics and biology (Ridolfi et al. 2011; Yarahmadian et al., 2011). The result shows that DMN as a novel stochastic approach can link the hydrological data and long-term decision making uncertainties to highlight the sensitivity of the rivers and ecosystems as a whole, to such decisions.

In this regard, all of the involved uncertainties are captured as random increasing/decreasing discharges of the water level modelled by DMN as a consequence of the associated decision. Therefore, the DMN model as a DSS acts as a tool to predict and estimate the overall nature of the increasing/decreasing river discharges, based on the long-term hydrometric data. River's discharge is directly calculated by water level, velocity and cross-section area-related relations. Water level is an important indicator of river decisions and of course is related to various interactions among the different components of the environmental-related systems that rely upon the organizational procedures involved in the management, and water resources of the river. The simplicity of this method is in providing a framework for the classification of the long-term behavioural of the river water level into the Overall Increasing Level (OIL) or Overall Decreasing Level (ODL) regimes (Zhao et al., 2012), which are differentiated by an exponential steady-state.

Afterwards, we use this classification to introduce a new nonparametric approach for the prediction through hypothesis applications applied to the real data. In this regard, it is important to mention that the parametric testing procedures for studying the monotonic trend in seasonal hydrologic time series are commonly confounded by problems such as non-normal data, missing values, seasonality, and serial dependence. On the other hand, appropriate nonparametric or distribution free statistical techniques are useful tools when data do not satisfy the conditions required by parametric statistical tests, and may be applied to a variety of hydrogeological problems.

2.1. Mathematical Framework

In this section we introduce Dichotomous Markov Noise for the modelling process of flow fluctuation.

2.1.1. Dichotomous Markov Noise

The dynamics of most environmental phenomena are stimulated by random behaviour. These behaviours are pervasive in nature. The underlying randomness, which is expressed as noise in the environmental dynamics, is the main cause of this variability. $L(t)$ is a continuous positive random variable, which represents the water level of the river under study in time. It is assumed that the rate of change of the water level randomly switches between constant positive and negative values $(v_{\pm})$ measured from the zero scale (See Figure 2).

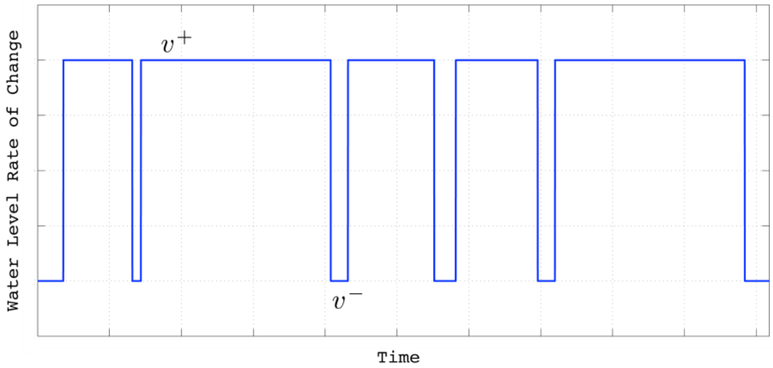

Figure 2 : The *Zayandehrud* water level rate of change

Dichotomous Markov Noise (DMN) is defined as a two-valued stochastic process with the state space values $\pm v_{\pm}$ with constant transition frequencies of $\lambda_{\pm}$, for the increase $(+)$ and decrease rate $(-)$ with the appropriate probabilities $p_{\pm}(t)$, (See Fig. 2). The switches of $v(t)$ are the Poisson process. The DMN is a coloured noise, i.e., a noise that has a non-negligible correlation time.

The evolution of $p_{\pm}(t)$, follows the following system of differential equations:

$$\frac{d}{dt}\begin{pmatrix} p_{+}(t) \\ p_{-}(t) \end{pmatrix} = \begin{pmatrix} -\lambda_{+} & \lambda_{-} \\ \lambda_{+} & -\lambda_{-} \end{pmatrix}\begin{pmatrix} p_{+}(t) \\ p_{-}(t) \end{pmatrix} \tag{1.1}$$

By using the initial values $p_{+}(0) = 1$ and $p_{-}(0) = 0$, the solutions are written as follows:

$$p_{+}(t) = \frac{\lambda_{-}}{\lambda_{-} + \lambda_{+}} + \left(1 - \frac{\lambda_{-}}{\lambda_{-} + \lambda_{+}}\right) e^{-(\lambda_{-} + \lambda_{+})t} \tag{1.2}$$

$$p_{-}(t) = \frac{\lambda_{+}}{\lambda_{-} + \lambda_{+}}\left(1 - e^{-(\lambda_{-} + \lambda_{+})t}\right) \tag{1.3}$$

Stating the average rate (expected value of $v(t)$) as $\bar{v}(t) = v_{+} p_{+}(t) - v_{-}p_{-}(t)$, the average rate and the equilibrium point can be calculated as:

$$\bar{v}(t) = \frac{v_{+}\lambda_{-} - v_{-}\lambda_{+}}{\lambda_{-} + \lambda_{+}}\left(1 - e^{-(\lambda_{-} + \lambda_{+})t}\right) + v_{+}\, e^{-(\lambda_{-} + \lambda_{+})t} \tag{1.4}$$

$$V = \lim_{t\to\infty} \bar{v}(t) = \frac{v_{+}\lambda_{-} - v_{-}\lambda_{+}}{\lambda_{-} + \lambda_{+}} \tag{1.5}$$

Remark 1.1. The equilibrium point of the system is characterized by V, which classifies the water level in three different regimes. Figure 3 shows that, when $V > 0$, water level increasing events are more frequent and the water level is in an Overall Increasing Level (OIL) class, whereas for $V < 0$ the decreasing events are more frequent and the water level is in an Overall Decreasing Level (ODL) class. ODL class is interpreted as a balance between the level increasing and decreasing events, which produce a steady-state mean water level.

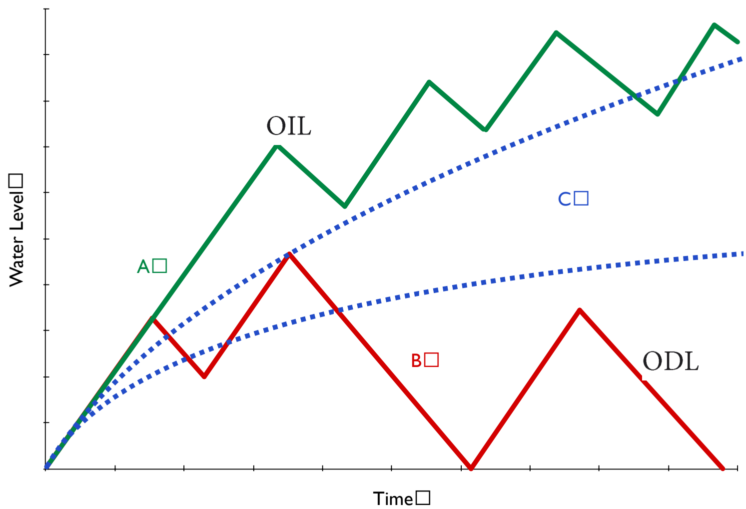

Figure 3: Overall Decreasing Level and Overall Increasing Level regimes

Schematic plots of the water level (solid green and red lines) for the OIL (A) and ODL (B) regimes. Average water level (dashed blue lines) increases in the case of the OIL regime and reaches a steady-state value in the case of the ODL regime.

Now, consider the probability $P_{\pm}(\mathrm{L},\mathrm{t})$, the probability density function of the increasing (decreasing) water level in the interval $[\mathrm{L}, \mathrm{L}+\delta\mathrm{L}]$. The following lemma explains the derivation of the steady-state probability density function.

Lemma 1.1 In steady state, the probability distribution function (pdf) and the mean of water level are obtained through an exponential distribution $P(L) = \frac{1}{\Lambda} e^{-\frac{L}{\Lambda}}$ and $\Lambda = \frac{v_+ v_-}{v_- \lambda_+ - v_+ \lambda_-}$ respectively.

Proof. The time evolution of probability distribution function $P_{\pm}(L,t)$ is according to the differential equations (see Ridolfi et al., 2011, page 18-19 for the derivation of these equations):

$$\frac{d}{dt}\begin{pmatrix} P_+(L,t) \\ P_-(L,t) \end{pmatrix} = \begin{pmatrix} -v_+\frac{\partial}{\partial L} - \lambda_+ & \lambda_- \\ \lambda_+ & v_-\frac{\partial}{\partial L} - \lambda_- \end{pmatrix} \begin{pmatrix} P_+(L,t) \\ P_-(L,t) \end{pmatrix} \quad (1.6)$$

Setting the time derivative equal to zero, (1.6) reduces to

$$\frac{\partial^2 P_\pm}{\partial L^2} + \frac{1}{\Lambda}\frac{\partial P_\pm}{\partial L} = 0 \quad (1.7)$$

This equation together with $\int_0^\infty [P_+(L) + P_-(L)]\, dL = 1$ will establish the result.

2.2. Application of the Proposed Methodology

2.2.1. Case Study Description

Zayandehrud is the most important river in the central part of Iran (See Figure 4). Situated on the Central Plateau of the country, it flows from west to east for 200 miles (for the basin's other characteristics see Table 2).

Zayandehrud is a Persian name, which means 'Procreator River'. Originating from the *Zardkuh* Mountain, it irrigates many gardens and farms. *Zayandehrud* is considered as the main source of verdure and fertility in Isfahan[11] city and the region. As already was mentioned, since 2000, the farmers and riparian city dwellers of the *Zayandehrud* River have been facing continual and drastic water shortages, while they had been expecting new water resources. The causes of the phenomenon are still incompletely understood. Molle and Mamanpoush (2012) believe that 'basin over building' and disordered (fuzzy) decision makings have caused a lot of problems for the river. They finely name it 'socio-ecological breakdown'. The *Zayandehrud* has been influenced by diverse and sophisticated decisions of decision makers, e.g. fiat allocation of water (Molle and Mamanpoush, 2012). As such,

[11] Also Esfahan; in the thesis, both words are identical.

having a comprehensive view needs methods that predict the river's long-term circumstances (Molle et al. 2008).

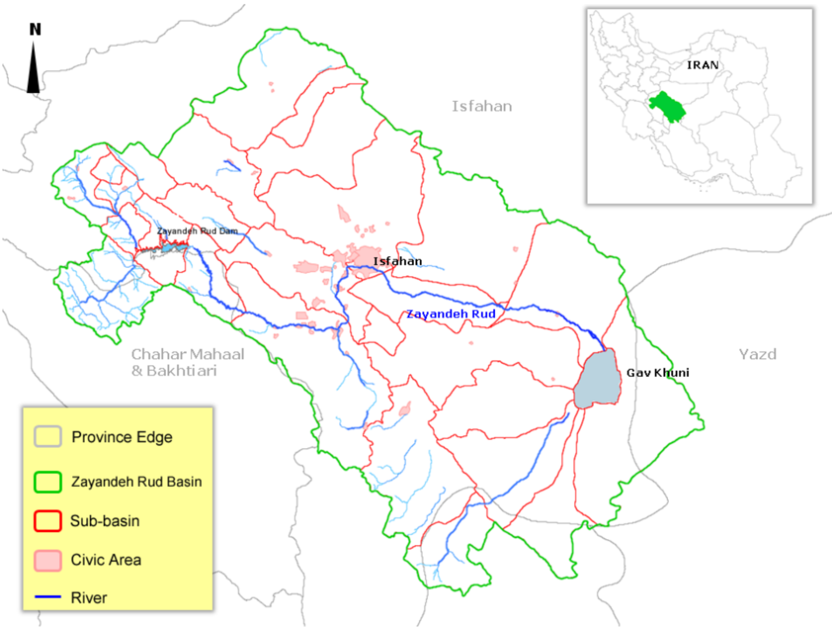

Figure 4: The *Zayandehrud* basin (retrieved from http://www.iwrm-isfahan.com)

Table 2: Overview of the study area (Madani and Mariño 2009)

Metric	Value	Metric	Value
Total area of the basin (km^2)	41,524	Gavkhuni marsh minimum required input flow (mm)	70
Elevation range (m.a.s.l)	1,470–3,974	Total area under irrigation (ha)	260,000
Annual average precipitation range (mm)	50–1,500	Irrigation efficiency range (%)	35–39
Average temperature range (°C)	3–30	Annual economic development rate of the basin (%)	4.2
Annual potential evapotranspiration (mm)	1,500	Share of agricultural section from the total consumed water (%)	90
Zayandehrud River length (km)	350	Share of industrial section from the total consumed water (%)	5
Natural average flow of *Zayandehrud* (mcm/yr)	850	Share of domestic section from the total consumed water (%)	5

2.2.2. Analysis of stochastic characteristics

The traditional water-related question is about the pattern: is there any pronounced pattern in the river water level? Studying the past trends in stream flow enables us to develop strategies for the better utilization of water resources in the future. There is a huge amount of literature on the development of useful balance models in Real-time River Management. We refer the reader to the work of Conway 1997, 2000; Kebede and Travi 2006; Abdul Aziz and Burn, 2006; Burn and Elnur 2002; and Burn et al. 2004.

The *Zayandehrud* River data after man-made changes, observation at th downstream of the dam.

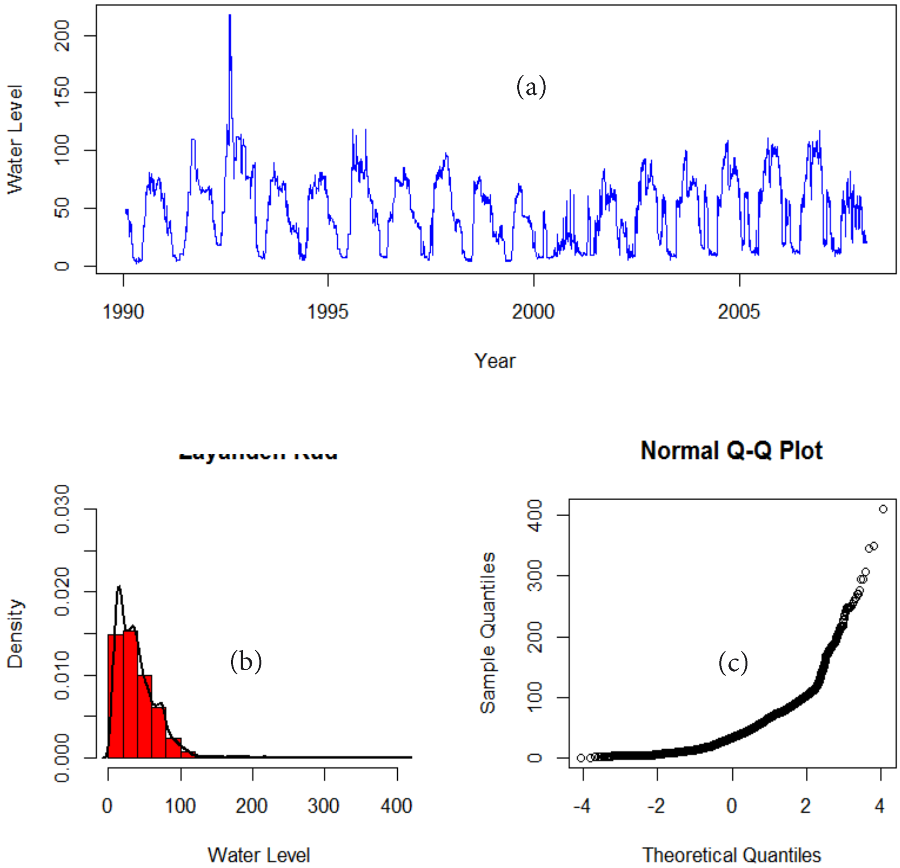

Figure 5: The *Zayandehrud* water level series

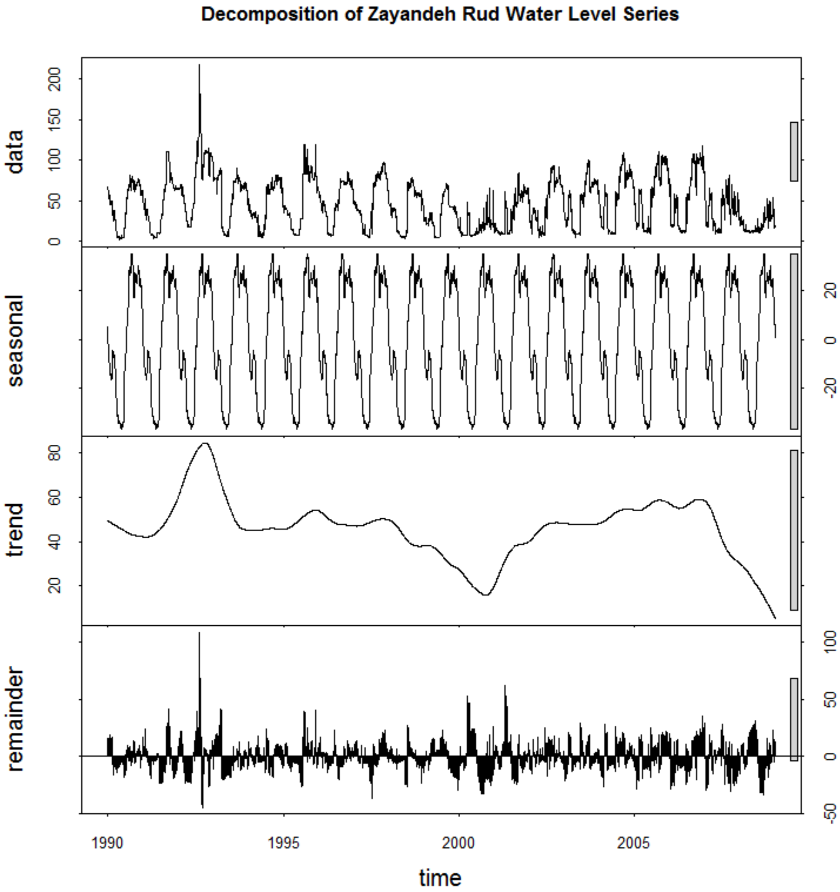

Figure 6: Additive decomposition of the *Zayandehrud* river data*

*- In the additive model, the observed time series is considered to be the sum of three independent components: the seasonal, the trend and the remainder.

Observed series = Trend + Seasonal + Remainder

The trend component reflects the long-term progression of the series (secular variation); the seasonal component reflects seasonality (seasonal variation) and the remainder component (or "noise") describes random, irregular influences and represents the residuals of the time series after the other components have been removed.

2.3. A nonparametric approach

The *Zayandehrud* water levels during 1990- 2008 are shown in Figure 5a. The diagram presents the stochastic dynamics of the water level over the years.

Remark 2.1. We have assumed that the *Zayandehrud* water level follows the assumptions of the DMN process, i.e., the water level rate of change is stochastically switching between two constant levels. This can be partially justified by the fact that the dam as a regulator often imposes constant changes on the river discharge.

Different tests for the normality of the water level series (Table 3) along with the Q-Q plot (Figure 5c) reject the null hypothesis that the water level series has a normal distribution. In order to test the *stationarity* of the series on both level and trend, we have implemented the nonparametric Phillips-Perron test. This test computes the p-value as equal to 0.01. At 5% significance level, we reject that the water level series has a unit root in favour of the stationary alternative.

Table 3: Test for normality of the *Zayandehrud* water level series
(Notation ** indicates that the test is significant at the level of 1 %.)

Test for normality	p-Value
Jarque-Bera	< 2.2e-16 **
D'Agostino	< 2.2e-16 **
One-sample Kolmogorov-Smirnov	< 2.2e-16 **

DMN classifies the water level into two different regimes of ODL and OIL, which are separated by an exponential steady state (see Remark 1.1). In the following section, we provide the probabilistic characteristics of ODL and OIL classes of water level distribution.

2.4. Moment inequality approach

Let $L_1, L_2, \dots, L_n$ be a sequence of independent identically distributed random water levels with survival function $\bar{F} = 1 - F$ and finite mean Λ (See Lemma 1.1). Applying Lemma 1.2 shows that in steady state ($V = 0$), the boundary member for the aforementioned classes, ODL or OIL, is an exponential distribution.

Theorem 2.1. If water level distribution F belongs to the ODL class, then for all integers $r \geq 0$

$$E\left\{\frac{1}{2(r+1)} L_1^{r+1} L_2^2 - \frac{1}{r+2} L_1^{r+2} L_2 + \frac{1}{2(r+3)} L_1^{r+3}\right\} \leq$$
$$\Lambda E\left\{\frac{1}{r+1} L_1 M_{1,2}^{r+1} - \frac{1}{r+2} M_{1,2}^{r+2}\right\} \quad (2.1)$$

where L_1, L_2 are two stochastically independent copies of water level L and $M_{1,2} = \min(L_1, L_2)$, and $E\{L\} = \int_0^{+\infty} l\, dF$ which is the expected value of random water level L.

Corollary 2.1. Setting $r = 0$ in (2.1):

$$E\left\{\frac{1}{2} L_1 L_2^2 - \frac{1}{2} L_1^2 L_2 + \frac{1}{6} L_1^3\right\} \leq \Lambda E\left\{L_1 M_{1,2} - \frac{1}{2} M_{1,2}^2\right\} \qquad (2.2)$$

The goal in the next section is to test if overall the water level falls in the ODL class.

Remark 2.2. The reader can find the proof for the theorem and corollary (2.1) in (Sepehrifar et al., 2012).

2.5. Statistical testing

We define the following measure of departure from the null hypothesis to test the null hypothesis that the water level in the long-term falls into the steady state (H_0) against any other alternatives in the ODL class (Sepehrifar et al., 2012):

$$\delta = E\left\{\frac{1}{2}L_1L_2^2 - \frac{1}{2}L_1^2L_2 + \frac{1}{6}L_1^3 - \Lambda\left(L_1M_{1,2} - \frac{1}{2}M_{1,2}^2\right)\right\} \qquad (2.3)$$

Note that the test statistic$\Delta = \frac{\delta}{\Lambda^3}$ has the scale invariate property with value $\Delta = 0$ under the null, and $\Delta < 0$ under the alternative. Now, let $L_1, L_2, \dots, L_n$ denote random samples of F. An estimated form of Δ is $\hat{\Delta} = \frac{\hat{\delta}}{\bar{L}^3}$, where $\bar{L} = \frac{1}{n}\sum_{i=1}^{n} L_i$ and

$$\hat{\delta} = \frac{2}{n(n-1)} \sum_{1 \le i \le j \le n} \left\{\frac{1}{2}L_iL_j^2 - \frac{1}{2}L_i^2L_j + \frac{1}{6}L_i^3 - L_i^2M_{i,j} + \frac{1}{2}L_iM_{i,j}^2\right\} \quad (2.4)$$

To perform this test, we calculate $\hat{\Delta}$ from data and reject H_0 in favour of an alternative if the normal variate value $z_{1-\alpha}$ exceeds $\hat{\sigma}_0^{-1}\sqrt{n}\hat{\Delta}$. In this calculation, one may find the value of variance through the following theorem (see Sepehrifar et al., 2012):

Theorem 2.2. As $n \to \infty, \sqrt{n}(\hat{\Delta} - \Delta_0)$ has an asymptotically normal distribution with mean *0* and variance

$$\sigma^2 = \frac{1}{\Lambda^6} Var\left\{\frac{1}{6}L_1^3 + \frac{1}{6}\int_0^\infty l^3 dF(l) - \frac{1}{2}L_1^3\bar{F}(L_1) + \frac{3}{2}\left[L_1\int_0^{L_1} l^2 dF(l) + \int_0^{L_1} l^3 dF(l) - L_1^2 \int_0^{L_1} l dF(l)\right]\right\} \qquad (2.5)$$

under the null hypothesis $\hat{\sigma}_0 = 1.173$.

The test statistic for this data set is $\hat{\Delta} = -1.320264$. At %5 significant level ($\alpha = 0.05$), $\hat{\sigma}_0^{-1}\sqrt{n}\hat{\Delta} = -29.436809 \ll$ -1.644854. Thus, from this calculated value, we must reject the null hypothesis and we conclude that the *Zayandehrud* water level series has the ODL property. This result shows an overall decreasing change in future for the Zayadeh-Rud River, which requires a proper series of decision actions. Figure 5 (Trend) also shows the decline in water level trend for this specific data set.

2.6. Conclusion: the level falls in the decreasing level

Rivers' unpredictability during the course of time and space and the influence of different parameters complicate the study of their long-term behaviour. This study proposes a new analytical framework that monitors and predicts river water level decreasing (increasing) long-term behaviour with a statistical river life analysis. In particular, water level is viewed as a dichotomous process with constant transition rates. Then a nonparametric testing procedure was applied to test if the water level driven by the DMN falls in the decreasing level (ODL) class or not.

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CHAPTER 3

An Appraisal of Qualifying Role of Hydraulic Heritage Systems; a Case Study of Qanat in the Central Iran[12]

[12] As the main author, I have already published a version of this chapter as Harandi, M. F., De Vries, M. J., 2014. An Appraisal of Qualifying Role of Hydraulic Heritage Systems; A Case Study of Qanat in the Central Iran, in: Journal of Water Science and Technology: *IWA Water science and Technology: Water Supply Journal* **14**.6: 1124-1132.

Index Terms: *aqueduct, hydraulic heritage system, underground water supply network, technological development, Qanat technology.*

Hydraulic heritage systems, such as Persian underground 'water supply networks', have been known to be sustainable (English 1998) for millennia. For many years these water supply systems have been facing diverse and adverse contradictions mostly of a 'utilitarian nature' (Martínez-Santos and Martínez-Alfaro 2014) of engineering heritage linked to modernism. They have by far been overtaken by engineering infrastructure and were deemed as a hindrance for modern technological development.

Although there are exceptions, quite a few of arid and semi-arid areas are still dependent on hydraulic heritages. Among them are Qanats, which as a socio-technical system tend to have a '*functional interconnectedness*' interactively with the surrounding society and ecology. However, these areas are accommodating more people than they can sustain (Mays, 2007), and increasingly such less sustainable urbanization growth is manipulating this connection explicitly or tacitly.

There are floods of studies that have identified the worldwide importance of hydraulic heritage systems. Lofrano et al. (2013) illustrate Qanats elements that made Bal'harm (Palermo's name in the Middle Ages) 'a flourishing town'. Voudouris et al. (2013) link the ancient Greeks' water management skills to 'aqueduct-like' Qanat technology that was developed by Persians in the middle of the 1st millennium BC. There are concerns about dealing with Qanats, as Motiee et al. (2006) highlight notions of 'traditional water management', rehabilitation and the renovation of Qanats and Qanats' rights, particularly for large urban areas. Hosseini et al. (2010) and Martínez-Santos and Martínez-Alfaro (2014) have also documented the effects of urban sprawl upon Qanats in the North-East of Iran and Madrid, respectively.

In the present chapter, we will try to raise questions concerning the disregarded functions and early and historical positions of hydraulic heritages by looking at Qanats. This chapter focuses on the issues surrounding the *roles of Qanats* in one of the Zayandeh-Rud River regions in the vast province of Isfahan in Iran. We will contribute to these scientific approaches by notion of qualifying role to answer the leading question in the chapter: the fact that the role of Qanats should be considered during the processes of development because of their qualifying role. By qualifying role I mean, Qanat still deserves itself to contribute in hydrosystems development processes.

The Qanats' qualifying role raises questions concerning the disregarded functions and early and historical positions of these hydraulic heritage systems. This is shown by a successful case study in Riz, a suburb of the historical and industrial city of Isfahan, where the construction of a drainage system modelled on Qanats' bygone techniques resulted in a dramatic drawdown in the water level of the area soon after construction. The chapter will first describe the history and technology of Qanats in Persia/Iran from a bird's eye view. Then the chapter will describe the problematic side effects of the development of the city on Qanats and describe how one of these causes was tackled by turning back to a more traditional approach, Qanat revitalization.

The chapter will attempt to present the case according to interviews with people living in the area, an appraisal of the last vestiges of the old Qanats, survey of the data from engineering literatures (i.e. reports and drawings on the sewerage and water distribution systems), as well as procedures and practices to support different affirmations of using a revitalized Qanat as a drainage system for the city.

3.1. Qanat technology and its mutual interaction with modernization in Iran

3.1.1. Technical function

The term Qanat comes from a 'Semitic word meaning 'to dig'' (Stiros 2006) and over the centuries, this technology was transferred to other civilizations and become known by different names such as: *Hydragogeion*, e.g. aqueduct (from the words *hydro* = water and *agogos* = conduit, Greek), *Karez, Kariz, Kahriz*, (which are derived from the Persian the word *Kariz*), *Foggaras, Fughara, Khettras* (North Africa and Spain) and the Chinese definition of *kan'erjing* (Hu et al. 2012). Various definitions of Qanat are also listed in Voudouris et al. (2013, p. 1341). Apart from Persian altitude-based aqueducts such as what we see in Chogha Zanbil, the elaborate Qanat system was 'arguably invented' (De Feo et al. 2013) and 'practiced' (Pazwash 1983) in Persia some centuries B.C. and was gradually introduced to Egypt, India, China and Spain in 500 B.C. Stiros (2006) represents Qanat's as benchmark in the civilization for many arid areas' as Pazwash (1983) has called Qanats 'the most extraordinary works' of the Persian people for collecting water.

Technically speaking 'qanats are gently sloping tunnels used to tap and convey shallow groundwater' (Martínez-Santos and Martínez-Alfaro, 2014) by gravity (Wulff 1968). They are cleverly hidden and carry the invaluable water in the deserts tens of miles away to reach to the destinations. For practical purposes, they are best described as 'horizontal wells' (Cressey 1958). In terms of 'structure', a Qanat consists of an inclined conduit (traditionally named, *Kureh*[13]), crossed with many vertical ventilation shafts (traditionally named, *Mileh*[14]) and connected to the

[13] کوره

[14] میله

ground surface. The shafts also serve purposes such as hauling up the excavated materials; indicating the direction of the tunnel during the construction phase and performing maintenance during the exploitation phase (see Fig. 7). The inner radius of the tunnel is reinforced by earthenware hoops (traditionally named *Kaval* and *Goom*[15]). Qanats in terms of a 'pattern' can be divided into mountainous and flatland types, of which the latter are mostly branched from rivers. Qanat technology has many similarities with tunnelling but crucially needs a basic knowledge of groundwater fluxes in addition to an accurate surveying, based on astronomy and the precautionary principle of safety related to ventilation.

As its main function a Qanat conveys water from upstream through downstream by gravity. Depending on their patterns, Qanats capture groundwater from rivers or alluvial fans by providing a 'preferential drainage path' (Martínez-Santos and Martínez-Alfaro 2014) (i.e. tunnel or gallery) below the water table. Drainage as one of the Qanat's function is widely overlooked, alongside their other technical functions such as water supply, conveyance and distribution, a source of energy for water mills (Hussain et al. 2008 and Jomehpour 2009), soil salinity balancing and non-technical roles such as social partnerships. Jomehpour (2009) has also described these roles as a *specific function* of Qanats. The next sections will show how this technology can qualify as a method for resolving drainage issues. Before addressing the method, I probe the mutual interactions of Qanats as a socio-technical hydrosystem with urbanization growth and Iran's modernization era in the recent past.

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[15] کَول و گوم

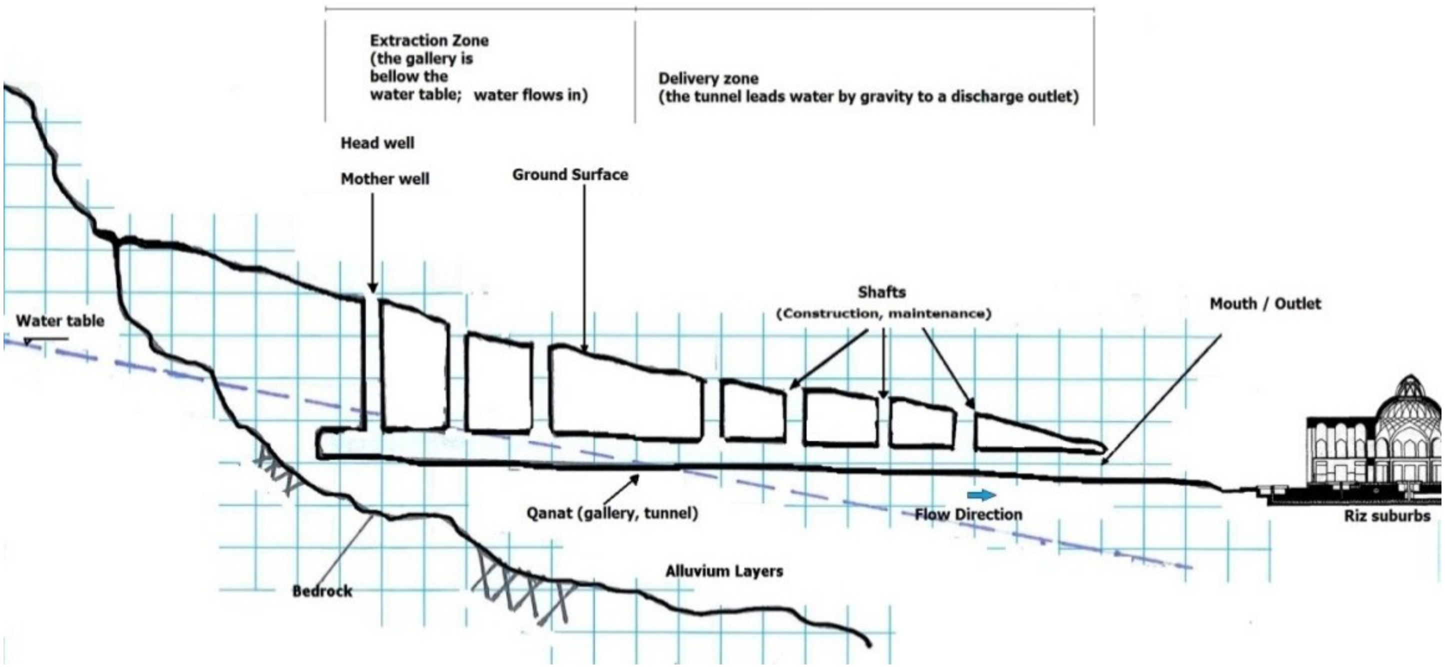

Figure 7: A Qanat scheme (Drawn by author, and descriptions are derived from Martínez-Santos and Martínez-Alfaro 2014)

3.1.2. Iran's mode of development and Qanats

Recently a narrower, more modernist approach has eventually led to serious problems in the functioning of the Qanats. This approach originated in the early 1960s and has been strengthened in recent decades. It predominately rooted in 'a modernist ethos that considered traditional village irrigation [systems] as primitive' (Molle and Mamanpoush 2012), and increased the pace of Iran's hydro-oriented so-called development. This was fostered by a copied plan to develop agriculture as a backbone for large industrial development (Balali 2011). Water-harnessing projects including the construction of reservoirs and digging wells to irrigate farmlands were at the centre of all these projects (Ettehad 2010), which were 'ill-conceived and ill-suited to Iranian conditions and needs' (Afshar 1981).

Therefore then there was a continual modern Western view in Iran's mode of development, which gradually became a strong conviction, to look at 'the natural environment as the object to be conquered' (Wang and Zhu, 2012). It certainly deems the Qanats' technology as a seeming hindrance for progress and outdated technology, has unintentionally marginalized, destroyed and dried up them, particularly those Qanats that adjoined cities (Jomehpour 2009 and Hosseini et al. 2010). They were dramatically replaced by more productive but less sustainable engineering heritage systems (i.e. dams and deep wells) (Afshar 1981 and English 1998). However, the farmers and city dwellers who had initially resisted finally bowed to these practices and their transient/short-term and unsustainable benefits. Molle et al. (2004) explain the story of the unfettered development in the case of wells; 'the development of wells in the villages competed with, and impacted on, both local Qanats that supply the same communities and downstream ones, because of the resulting critical uptake of groundwater'.

Molle and Mamanpoush (2012) also denounce such development and its subsequent diversifying of the sources of water that tends to override the Qanats' rights. As they hold, freeholders got into the 'business of well digging despite reservations and awareness that Qanats might be impacted', and intuitively, massive drilling in aquifers caused overexploitation of groundwater. What we see now is that this unbridled well drilling has exhausted aquifers and caused the abolition of the historical investments and rights vested in the Qanats that had supplied water to towns and villages for millennia.

These measures often threatened the performances of Qanats, including water conveyance, recharge and drainage functionality (De Feo et al. 2013 and English, 1998), and Qanats could no longer support the regions' overpopulation (France 2007). Imperceptibly, these ancient assets were wasted; whereas in 1968, more than 75 per cent of the water used in Iran was provided by Qanats, now a large proportion of the Qanats have been put out of operation[16], and those remaining are struggling to function because of the tiny amount of remaining water.

3.2. Characteristics, case description and problem background

The vast city of Isfahan and its suburbs have been supplied from the Zayandeh-Rud River, a river that is 400 km long and has a basin area of 41,500 km^2, and which flows from the Zagros mountains to the Gavkhuni swamp (listed under the Ramsar Convention) in the centre of Iran (Fig. 3). Two major characteristics in the case have highlighted the qualifying role of the Qanat. Firstly, the mountainous part of the basin culminates at around 2,300 m but the case study area, Lenjan District, Riz

[16] McLachlan (1988) and Beaumont (1989) estimate the number of Qanats in Iran between 30,000 and 50,000 whereas Karimi (2003) states this number had fallen to 27,481 by the year 1999

City - which after industrialization was named 'Zarrin-Shahr', which means Golden City - stands at a lower altitude, at around 1,550 m. Riz City is located on the relatively flat alluvial plain adjacent to the river. The sedimentation of the Zayandeh-Rud River has had a significant effect on the formation of the current topographic features of this region. It is surrounded by mountains in the North East and the East on the one hand, and the Zayandeh-Rud River in the south on the other hand, and this causes groundwater flows to the region. This affects the city, which is irregularly inundated by both groundwater and runoff and the ensuing dire need for drainage. Secondly, Iran's central plateau as well as this area is classified in the semi-arid zone with minimal and improper distribution rainfall and periodic drought and paucity.

Extension of the city was performed in light of the river's resources. Due to rich farmland, at a regional level, and major industries such as steel, chemical and military, at a national level, this area is of importance. Nationally, these industries, which have been developed based on the *Zayandehrud* River, boost the role of the region and have attracted population. Urbanization growth in this area, which was partly performed because of the river's resources, has firstly increased demand for projects related to facilities, and subsequently these projects have become a potential threat to Qanats. Because previously there were villages with flourishing farmlands relying on agribusiness, but now there are the city(ies) that are struggling with all the disadvantages of having two systems (cities attached to villages) mixed up and as a consequence the hydraulic heritage systems are threatened by such a mixed city-village system. However, as mentioned earlier, urban drainage is potentially a crucial issue in the case of runoff and high water tables and every year Riz City is faced with serious drainage problems; it is partly inundated and the groundwater bubbles up near settlements (Fig. 3b). Moreover, due to some areas with high bedrock and fine soil texture, drainage here is unavoidably required.

According to the Sheikh-Bahai scroll the Lenjan and Alanjan districts had 10 of the 33 shares of the river (Hossaini 2006; Pirpiran 2007), and moreover the districts have been largely dependent on groundwater as well as numerous springs and Qanats (Molle and Mamanpoush 2012). As mentioned earlier, in addition to water conveyance, Qanats drain water from the aquifer toward their outlet and the *Zayandeh-Rud* valley is already used to exploit this advantage. Indeed, this highlights the role of Qanats in regulating hydrologic cycles (storage and conveyance) and also in increasing the *Zayandeh-Rud* River flow with underground water flux. According to the local inhabitants, in the recent past, the *Hosseinabad* Qanat's task was partly to carry out the drainage of the farmlands (now the city) in addition to transferring and supplying farmland autonomously, efficiently and effectively with no externalities for the environment or society. Therefore the city district authority called experts to tackle the problems by close collaboration with all the stakeholders in the area. Habitual drainage and sewerage system ineffectiveness - in this particular case - has been frequently emphasized by various indications, such as water bubbling in the building, streets and sewerage manholes.

3.3. Methodological approach, scheme and results

Although there is no precise information on this, how long the case study has already been out of action, however the imbalanced developments of Riz City as well as previous factors have all contributed to the Qanat's destruction. These indications can be clearly seen in the construction of a sewerage system in the heavily urbanized parts and narrow streets of the city that cross over and are parallel with the Qanat's galleries and shafts. Many shafts of the Qanat had been filled with sewerage trench debris over the years before starting this project. The planners portrayed the performance of the *Hosseinabad* Qanat as a whole normative system that could be the starting point of rectifying and resolving the issue. At the outset, an appraisal of the known remains was carried out, leading to an inventory of galleries, shafts (some of which are now sewerage manholes) and deposits. This was followed by a thorough mapping and a survey of all the existing reports, including physical descriptions of the sewerage system and underground water level metering, among other documents.

In the study phase, the identified remains of the conduits and the evidence of damp, mould and condensation – which were a problem in- and outside the settlements - and also signs of groundwater that bubbles up near houses, all are the results of semi-structured interviews, as on-going interaction processes and informal conversations. Moreover, during the construction phase these site visits and interviews also represented how quickly the project proceeded when interviewees reported a one-meter drawdown decreasing in the water table in the basement of their homes and settlements. (*PayandAb Tavan* 2009).

The above methods identified the damaged sectors of the Qanat and also made it possible for engineers to find remains which were in good condition. Following the site visits (Fig. 4) and interviews, the engineers examined possible techniques for draining excess water in the district (*PayandAb Tavan* 2009) as well as drainage pipes and pump station(s). As a routine procedure in drainage projects, using a combination of buried pipes and pump-equipped drainage was proposed and evaluated as a serious alternative, but the functional advantages of the Qanat convinced the engineers to choose it over other alternative(s).

For designing a long-lasting drainage system, five main engineering variables were considered by the designers; the terrain changes, longitudinal profile of the conduit, normal water depth within the Qanat's gallery, maximum probable water table in the area due to backwater of the downstream farmlands' high water table and the height of the conduit. As such, the Qanat system was entirely divided into three sectors due to the construction limitations and mostly due to allocate an appropriate slope for the Qanat.

Surveying showed there are considerable differences in the terrain — upstream to the downstream outlet about 1.3 m, and a conduit could be planned with a very steep slope which is appropriate for construction of such a sensitive hydrosystem. The slope is very important in the Qanat for two reasons: firstly to avoid sedimentation and degradation and secondly to keep the conduit and the study area safe enough from probable backwater of the downstream's farmlands (the Qanat's outlet). As the old Qanat's conduit for one of the three sectors was completely clogged by sewage and there was no affordable access to it — because the old path is beneath the foundation of the settlements, a new open-trench conduit (see the cross section in Fig. 8) with a length of 800 meters and 0.001 slope was considered.

To check the system's flexibility, four scenarios for discharged drainage were examined. To some approximation, the calculations in Table 4 show that an eight-fold increase in drainage discharge would cause a six-fold increase in the conduit's water level, which is appropriate for a drainage system.

Table 4: Water depth calculations in the revitalized Qanat (different scenarios)

Calculated drainage discharge (cms)	Manning's roughness	Conduit slope	Water depth (m)
0.025	0.04	0.001	0.18
0.050	0.04	0.001	0.35
0.100	0.04	0.001	0.60
0.200	0.04	0.001	1.10

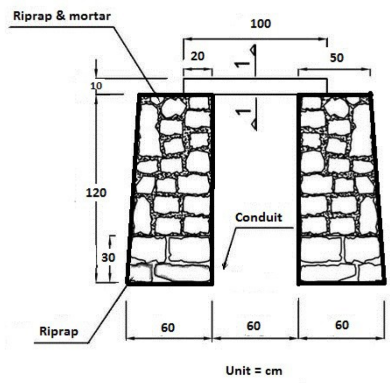

Figure 8: Typical cross section of the scheme; the concrete slabs (Section 1-1 in the figure) will be covered by aggregated soil.

Accordingly, conduit stabilization by means of one of the Qanat's digging techniques was implemented. This technique is an important advantage of the Qanat system that uses a sequence of materials consisting of the riprap and mortar-riprap, in the both sides of the gallery. The riprap in the bottom drains water through the porous media and the saturated area into the conduit. Ripraps also perform as retaining wall. This technique has been 'borrowed' from Qanat technology to build a permeable (and in fact stable) retaining wall in the drain's galleries, using cost-effective and locally available materials. On the top of the riprap and beneath the slab (refer to Fig. 8), mortar-riprap functions as support for slab.

One of the main social applications of this Qanat was in supplying the water required to perform ablution (Wudu) in mosques. Previously, water was supplied by the Qanat. Figure 9 (left) shows the water tail in the wall of the outdated Qanat's outlet and the situation (before the revitalization) of the traditional ablution place where the Qanat is exposed. It was fully flooded and blocked by sullage. As can be seen in Figure 9 (right), the water tail in the same place shows that the revitalized Qanat has drained the excess water within the saturated soil. Thus the Qanat safely performs the function of drainage in different scenarios of groundwater uncertainty, and lowers the water table in different circumstances with a high radius of influence in such an unconfined aquifer.

Figure 9: Sewage filled outlet of Qanat, before and a couple of days after revitalization.

3.4. Conclusions; '[D]oes a place still exist for traditional technology in modern[ist] water management'?

The chapter investigated the qualifying role of hydraulic heritage systems to tackle one of the issues that comes out of blind and engineered development. For this purpose a case study of a Qanat was examined to validate this argument. An urban drainage plan was modelled on Qanat construction skills and techniques to ensure the optimal long-term performance of the drainage system. Our case study placed a double emphasis on these questions: 'In our scientific and technical world, where water technology has developed based on a model of big infrastructure, water transfers, and inexhaustibility of the resource, does a place still exist for traditional technology in modern[ist] water management?' (Schneier-Madanes and Courel 2010) and how can a return to the traditional approach with its inclusion of social values (Balali et al. 2011; Jomehpour 2009) be used to resolve the issues. Certainly, it would be no exaggeration to say that the efforts of renovation and rehabilitation of a Qanat have resolved the drainage issue in a city.

The concept of qualifying roles in hydraulic heritage systems calls for three sets of profound questions: the first - and perhaps most obvious one – is to understand the performances and mechanisms which tend to be associated with development projects. Secondly, a set of questions concerns the introduction of the early and historical rights of these systems, in our case Qanats. The third set that the chapter raises is how a look back into recent history can skilfully contribute to resolving current water-oriented problems. It is of great importance that this chapter made these questions explicit. And yet again, the chapter has reiterated that Qanats are impressive technical and engineering feats. However it has certainly elucidated repairing and maintaining existing hydraulic heritage is doable and feasible, but it seems to construct them today under appropriate working and safety standards would make them very difficult and expensive. Therefore long-term usage of Qanats, as a drainage system will present possibilities for combination of an overlooked technology with infrastructure and knowledge that is available nowadays. For instance, as the techniques and excavation technology of Qanats have gradually changed (Stiros 2006), it might possibly be affordable now to apply new techniques of construction to effectively show the values of such systems. Namely, it could be suggested regarding the geotechnical aspects of Qanats using robots (Khorasan News 2012) that they can perform maintenance more easily and more affordably. Also the usage of Tunnel Boring Machines (TBMs), specifically to be designed for Qanats compared with tunnelling standards - can facilitate the excavation work and shrink the investment and maintenance costs of Qanats.

This chapter has also emphasised on social values and provide a naïve way of rethinking to policy-makers and engineers about to revise the water management strategies based on the sustainable and inherently dynamic rules of nature and 'historical water practices in the locality' (Dang et al. 2013). We have finally argued how engineering heritage systems can be built based on the commonalities of modern and traditional values. This contribution is a general criterion of hydraulic heritage systems as they always get along with nature and society. A Qanat in that sense is much attuned with the hydrological cycle, geological formation and ecology as well as the societal values of the region in which it is laid out. As we see Qanat as a socio-technical system, our view is very near with conviction of about harmonization, reciprocal unity and reliance of man and nature on technological development, especially where they stress the local rationality of adjusting measures to natural and environmental conditions and the relationship between the 'parts' and the 'whole' Wang and Zhu, (2012), which can be clearly seen from the abovementioned function of Qanats. However this view of harmonization might be deemed impertinent to our account because it comes from a relatively different ideology, culture and background; here we only wanted to point out that it is similar in both contexts. The planning, calculating, construction and handling skills and knowledge of Qanats have harmoniously contributed to the development processes. Due to a holistic approach to development, the Qanat has arguably potential trends relevant to sustainability issues of the technology and can resolve part of the water-based issues in a sustainable way.

Without doubt, modernism-linked technological development has 'grown more varied and complex and has by far surpassed the ancient technological methods' (Wang and Zhu 2012 p. 373); however, the human-technology-nature interconnectedness ought to be seriously considered and observed. We should definitely set the pace of progress within/between the parts (beings and technology) and the whole (nature, reality).

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Know the truth, and you shall know its people.

–Imam Ali (AS)

CHAPTER 4

Water Management: Sacrificing Normative Practice Subverting the Traditions of Water Apportionment: 'Whose Justice? Which Rationality?'[17]

[17] As the main author, I have already published a version of this chapter as Harandi, M. F., Nia, M. G., & De Vries, M. J. 2015. Water Management: Sacrificing Normative Practice Subverting the Traditions of Water Apportionment—'Whose Justice? Which Rationality?'. *Science and engineering ethics*, ***21***(5), 1241-1269. *doi*: 10.1007/s11948-014-9593-1.

Index Terms *—water management, normative practice, Mirab, modernism, holistic thinking, technological development*

4.1. The Chapter aims

Philosophers who are concerned about a sustainable future are explicitly facing an increasingly large challenge with questions about technological development and governance patterns. However, the inspiration of contemporary decision makers in water management is tied to heterogeneous technological patches that drive the development. These issues have raised various questions concerning water-management systems and their in(ter)ventions. Nearly all the prevailing questions are devoted to the problems emerging from 'faith in modernism' (Molle 2009) vs. holistic thinking in terms of development, 'modern water' (Linton 2010) and the 'paradigm shift' (Pahl-Wostl et al. 2011) in water management. In essence, our concern in this chapter is about the normative (what should happen) and the descriptive (what happens, and how) voices, both from the scientist's and the opinion maker's side. These voices are arousing movement (Pahl-Wostl et al. 2011) to alter such corporative, autonomous, and society-dependent systems into a partly automatic and fully technology-dependent system by changing the values and norms, and threatening the man-nature harmonization (Wang and Zhu 2012; Harandi and De Vries 2014). Whilst the modernist state-centred governance 'could be considered as the guarantor of social and environmental justice' (Molle and Mamanpoush 2012), we see it as 'a way[18]' (Heidegger 1954) in which utilitarian governance is fuelled by modernism and gigantism thinking (Heidegger 1954), often oblivious of holistic rationality. The debate on governance here is 'subject to underlying confrontations between rival and at times even incompatible intellectual

[18] *ein weg*.

and political traditions, which defend often irreconcilable opposing principles and values.' (Castro 2007).

The chapter's analysis is empirically grounded on the *Zayandehrud* River, a case study in Iran. The river is facing severe drought (Safavi et al. 2014) and for two decades has seen growing and diverse contradictions between the stakeholders. For instance, there are conflicts between the traditional right holders and the government over fuzzy and disordered water allocation (Molle and Mamanpoush 2012). For years they protested about the unfair allocation, uncertain diversion/apportionment and unbridled abstraction of water from the river. The analysis discusses the causes in terms of values and responsibilities of the water distributors and will illustrate how values in the water apportionment mechanisms in this river are being reshaped. It shows how the declined or altered responsibilities could change the objectives and lead to this contradiction. Therefore, we have elucidated issues surrounding the interlocking relations of such systems in the case of performance confines, roles, rules, responsibilities, interests, relations, and the ultimate purposes of actor(s) in water apportionment and its mechanisms to propose our idea. The idea is to detach, clarify and analyse such factors to see who was and is permitted to do what in the matter of values, and to see how a well-defined governance system have transformed to an adjacent-to- and part-of-governance system.

I will review the account within the history time lines to see the shift from old to new *Mirab*, the local name for water managers in ancient Iran, focusing on the Zayandehrud case study. I show the sequential man-made events that sort the *Mirab* into transitional paradigm changes, in fact a shift from a holistic way of thinking to a modernist way of thinking. In doing so, we will first briefly describe the characteristics of a holistic and a modernist approach. Then the chapter shows that the old *Mirab* has been inspired by holistic thinking while the new *Mirab* is a modernist. Moving to the theoretical section, we will analyse both the old and the new *Mirab* actors by using a philosophical approach called 'Normative Practice'. This is an approach that enables us to elucidate the values and norms of an actor as social (professional) practices. It also shows some already highlighted measures that isolate tasks and responsibilities from values and norms and this leads every related social activity to certain contradictions. An important concept in the study is the social and collective interactions in these water-management systems, which is why we will slightly extend the notion of 'a well-defined social activity' to 'a normative practice' in our theoretical framework. I have seen in the introduction that this results in a problematic situation and therefore this chapter will conclude by giving recommendations about how to recover valuable elements of the former holistic 'practice' without trying to turn back the clock and go back in history.

4.2. Modernism versus holism

Ostensibly, being and thinking in a modernist manner as well as behaving in this way, are relative notions of 'what' and 'when'. At least for the scope of this thesis we need to have a concrete base to avoid this 'relativism'. In doing so, first we explain the formation of modernism with an historical example linked to the water context and afterwards we will briefly describe how it has reduced the earlier holistic thinking, by focusing on three interrelated terms of development, nature and technology.

Among various debates about the relationship between these three matters we refer to Nye (2006) who maintains that technology matters have been deeply influenced by modernism. He describes the pertinence of profitability of technology, farming, energy and water prices by taking a few examples from the agribusiness in the USA. His allusions such as 'water fields when sensors say it is time' indicate how modernism has shaped and affected us, and how modern systems think in this sense. Due to such profound impacts, a detailed quote from Nye's remarks can show a very concise summary and historical formation trend of the matters relevant to technology and modernity:

[…], from pastoral New England to industrialized family farming in the Middle West to irrigated agribusiness, traces an arc of increasing productivity made possible by increasing investment in mechanization. In the first half of the nineteenth century, many believed such agricultural development illustrated how industrialization creates more wealth, more jobs, and more goods for all. In the United States, [functionalists] argued that more technical skill and more mechanical power led to a higher level of civilization. By 1900 such views had become orthodox. [i.e.], […] Between 1870 and 1890 [… the] factory productivity rose almost 30 present, while working hours dropped and real wages rose 20 present. Similar gains throughout the nineteenth century had radically improved daily life. People had more leisure time and more money to spend. Consumption of clothing, appliances, and home furnishings rose rapidly, and Thurston drew graphs to express […]" the trend of our modern progress in all material civilization[.]" Our mills, our factories, our workshops of every kind are mainly engaged in supplying our people with the comforts and the luxuries of modern life, and in converting crudeness and barbarism into cultured civilization. Measured by this gauge, we are fifty present more comfortable than in 1880, sixteen times as comfortable as were our parents in 1850, and our children, in 1900 to 1910, will have twice as many luxuries and live twice as easy and comfortable lives (Nye 2006: 91).

Modernity was gradually founded on economic growth, machines, labour and natural resources (Christensen et al. 2012). As technology 'became a world of networked dependencies' (Floridi 2013), river course networks 'came to be seen as the logical unit to optimize, or "unify" the multiple uses of surface water, and then as a planning unit for regional development'(Molle 2009) 19. In fact, it was developed by various 'policies' and 'models' to become a concept in the water management. These policies and models which were referred to as a 'concept' are all examples of 'technology-based material progress' (Jamison 2012). Jakobsson (2002) discusses how the modernist parliamentarianism thinking altered 'the traditional definition of the natural flow rule [and outdated the] traditional institutional rules of natural flow' to produce electricity. As a result, an ideological image associated with modernity and rationality was replaced to find no 'rivers untouched by man [anymore]' (Jakobsson 2002: 52).

As societies distanced themselves from 'adapting to natural imperative [and have moved toward] manipulating natural resources' (Blatter et al. 2001), the environmental degradations became more and more apparent. Therefore, reductionist tenets 'which are beyond human control and rational calculation' became prominent and neglecting the existence of meaning and rights of water figured (Blatter et al. 2001). We see several pieces of evidence from politicians and opinion-makers that calls humans to control and to conquer nature with 'utopian dreams of mastering nature' (Molle 2009) as well as Swyngedouw (1999), Swyngedouw et al. (2002) and Zwarteveen and Boelens (2014). Modernism – again

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[19] Molle (2009) explains more details about this concept, in France 'calming the wild river' and in Spain dividing rivers into 'administrative divisions' and authorities were suggested.

as a way of thinking - and development are reciprocal notions which need complementary endowers from pre-modernist holistic ontologies (Figure 1). Due to limitations of instrumental rationality, developers are still searching for 'renewed pre-modern concepts' (Blatter et al. 2001) which concentrate on 'water' as it exists. Holistic thinking has focused on the whole aspects of reality[20] beyond the idealistic and rationalistic calculations of '*homo technologicus*' (Floridi 2013). However, as shown in figure 10, unlike holism, modernism puts individuals at the centre of the 'objective universe' and entails the 'social construction of meanings of water' (Blatter et al. 2001: 4) to involve actors and communities in it.

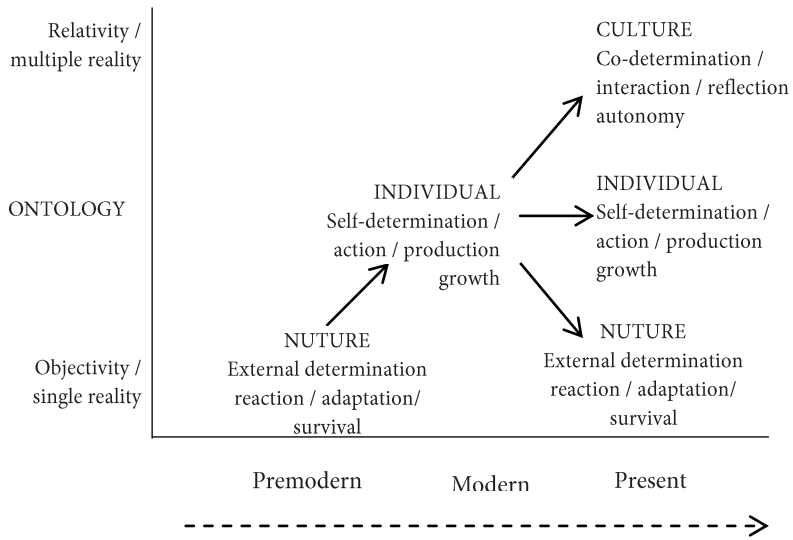

Figure 10. Transformations of ontologies over time (Blatter et al. 2001)

There are two more equivalent and distinctive criteria for modernism, upscaling and unification. Modernism makes an endless attempt to turn societal-control

[20] Refer to Basden, A. 2011. A presentation of Herman Dooyeweerd's aspects of temporal reality'. *International Journal of Multi-aspectual Practice*, **1**(1).

systems into an upscaling management method, which have partly featured the command-and-control style of management such as Integrated Water Resource Management (Schoeman et al. 2014). In fact, such processes started and happened during the Industrial Revolution, and that is when modernism actually began. Modernism also strongly believes in unification, in which all products start looking 'alike' because they are mass–produced. To continue we need to stretch and interpret our description to technological development in the hydrosystems domain, to show what exactly the rules of modernism and holism are, in that case.

4.3. The modernism ethos of hydrosystems' technological development in Iran, a 'Blue Rush'

It is several centuries since Iran started the 'holistic design of hydraulic structures' (Emami 1998) and hydrosystem development (Lambton 1953) where the glorious aqueducts and dams were constructed (Pazwash 1983). After WWII Iran became one of the most critical areas affecting world peace and security because of the location, resources and financial circumstances of the people. These formed the basis that after-war powers saw Iran as a land 'to carry on technical collaboration' (Harris 1953). The agrarian society of the country was transformed into an industrialized agriculture linked to government subsidies for livelihoods. Probably the then-developers did not fully realize that they were following a '*hydraulic mission*' in concordance with Iran's early 20th century's patterns of westernization. Molle, et al. (2009$_a$), based on work by Reisner (1993) and Swyngedouw (1999), define it as:

> the strong conviction that every drop of water flowing to the ocean is a waste and that the state should develop hydraulic infrastructure to capture as much water as possible for human uses. The carrier of this

> mission is the hydrocracy who, based on a high-modernist world-view, sets out to control nature and 'conquer the desert' by 'developing' water resources for the sake of progress and development.

The White Revolution of 1962 was supported scholarly by Utah University under the Point IV Program[21] that set out to improve education, agriculture and health in the rural areas. The downstream portions of the *Zayandehrud* River were the very first parts of the demonstration centre of the program. Harris (1953) mentions that heavy machinery was imported for drainage and deepening the main canal(s) from the river 'to secure more water and to soak up the water when the river was high' and water would be stored for use during the dry seasons. This situation was pervasive when the Qanats, a gravity-based water system, was gradually overlooked, demolished and replaced by wells (Balali 2011; Molle and Mamanpoush 2012; Harandi and De Vries 2014). Regarding such a huge development and westernisation, Iran's government succumbed to calls for 'hydrocracy' with entrusted companies by outsourcing the water distribution tasks and responsibilities by contract agreement. In pursuing this increase, the companies were established by the government to distribute the water in the modern hydrosystems mostly downstream of large dams. The *Mirab* is one of these companies which were 'rolled' into the *Zayandehrud* hydrosystems. Iran's 1968 Land Reforms dramatically swept away the roles of traditional water management in the *Zayandehrud* River governance in central Iran (Harandi and De Vries 2014).

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[21] Utah State Agricultural College's president was the first *technical* director of the Commission for Rural Improvement in Iran of this program.

Mahmoudian (1969) obliquely, and (Hossaini 2006) explicitly, both state that the traditional management system in Iran had ended by 1968.

4.4. **Old Mirabs' role in water governance patterns**

A comprehensive literature review by Singh (2014) has revealed that the 'management models used in the past' in hydrosystems mainly considered the objectives of maximization of net farm income, minimization of waterlogging, and minimization of groundwater depletion. Conventionally, governing water in the semi-arid areas such as Iran had intrinsic values (Mahmoudian 1969) as it was a societal-based activity. The main result of such governance was the management of river-diverted systems and Qanats[22] which was performed through an intricate system, known as *Mirab*[23]. The Farsi expression *Mirab*[24] for '*water management*' in English consists of two words: *Mir* and *Ab*. *Mir* usually indicates a person who steers others and also sometimes refers to colonels in the ancient Iranian military hierarchical ranking, and -*ab* solely means *water*. Therefore we can describe *Mirab* as head of the river and a person who apportions water-share to the water-right holders.

The old *Mirab*s' tasks and responsibilities are explained and praised in many literatures. Balali (2011) has an extensive description about *Mirabs* (and their subordinates) functional reasoning which they worked on the base of social

[22] Qanats are gently sloping tunnels used to tap and convey shallow groundwater by gravity.

[23] However, Qureshi (2002) differentiates between four similar positions for a *Mirab*'s management throughout the traditional hydrosystems: small-scale, large-scale, shallow wells, and springs.

[24] رآب

institution and ethical-religious frameworks[25]. Mohmand (2011) quotes from Thomas and Ahmad (2009) about *Mirab*s' duties: 'The distribution of water is done through the system of *[S]aat*[26] [literally time] (the allocated time interval of water flow allowed in each cycle in proportion to the landholding of the farmer) and *[N]aubat* (the order in which the water flow is allowed in each cycle). Conflicts on the water distribution were resolved through the collaboration of the *Mirab* (and subordinates), the *Arbab*[27] (village elder) and sometimes also the *[S]hura*[28] (village governing committee).' Hossaini (2006) has an elegant interpretation about the old *Mirab* election when he described it as 'democratic' since the *Mirab* was clearly voted for and elected by a very transparent ballot. Mehraby (2010) also introduces the *Mirab*: 'the distribution of the water has to be under a trustworthy official known as a *Mirab* who is chosen by the joint users or the government and is paid a certain salary.'

In sum, the *Mirab* was charged with the responsibility of ensuring that the enforcement of regulations was even-handed and consistent. Essentially, the appropriate performance of these systems was owed to the *Mirab*'s engineering and ingenuity and also its skills in connecting the needs and desires of the actors to water-inherent uncertainties. One of the reasons for this was that the *Mirab* had overall responsibility for supervising all of a river's tertiary water courses (Fig. 11) which diverted water from the secondary to individual farms, whilst individual farmers might be chosen to coordinate the *Mirab's* tasks (Qureshi 2002; Hossaini

25 In the Zoroastrianism and Islam

26 ساعت

27 ارباب

28 شورا

2006). We believe that the second reason is that water diversion, and allocation and distribution of the quantity of water flow should be carried out entirely according to the individual water rights related to the farmer's landholdings through a documented system and within detailed dates.

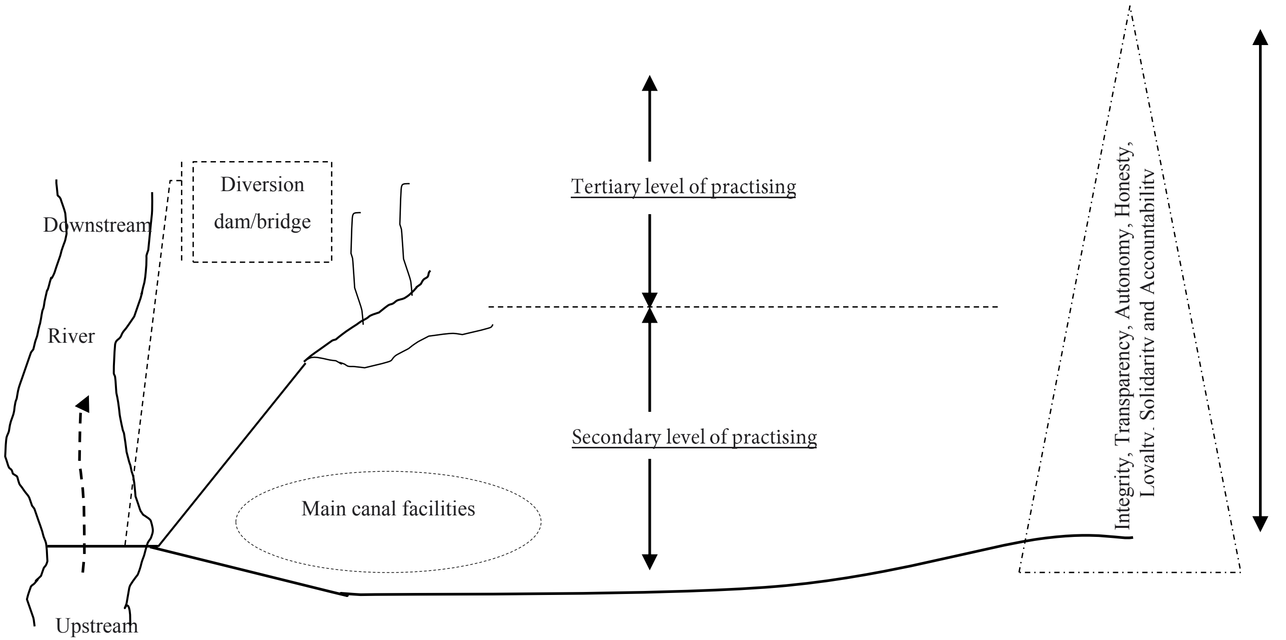

Figure 11: Schematic view of a river: an old *Mirab*'s area of activity (The general scheme derived from Qureshi 2002)

4.4.1. The Old *Mirab*'s role in the *Zayandehrud*

According to *Sheikh-Bahai's* edict (*Tumar*), written in July 1517(923 AH), *Zayahdehrud* River water is apportioned into 33 portions for 6 districts[29] (*Boluk)* (Mahmudian 1969). According to Hossaini (2006), the *Tumar*'s regulation is based on geographical views (socio-spatial) which included villages and hamlets and the *Boluks* of the river. The *Tumar* describes in detail the shares of the shareholders in relation to the *Boluk*s. Three levels of water allocations were designated by the *Tumar's* regulations attuned with the available resources, location, needs and the extent of cultivated tracks. The types of cultivation were precisely managed by the *Tumar* rules according to the available amount of water. It regulated the appropriate water flow for the whole range of users including *Gavkhuni*, the marsh ecosystem where the river terminates.

To devise the governance patterns in the river, the management system was largely local resource- and knowledge-dependent and was implemented according to precise technical- and societal-tuned mechanisms. In fact the *Mirab* was a trustworthy person who was elected by elders of the riparian communities and a representative from the state governors. The *Mirab* was well respected and had a high status and others would trust him for fair distribution of water according to the rules of the edict. For balancing and tracking equity, the *Mirab* ought to be selected from the middle reaches of the river (Fig. 2), to see the water from a normal viewpoint, not from the high water of upstream users or the low water of the downstream peoples (Mahmudian 1969). The *Mirab* should appoint 6 assistants

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[29] The *Tumar* (طومار) in traditional bureaucracy was used for very important rules. It could be argue that water allotment in this way has been crucial for farmers and water users since the sixteenth century.

(*Keshik*[30]) and quite a few watchdogs – all from the farming society- to distribute water in the *Maadi* (literally predicates the channel) through the farmlands. The overseers' obligation was unending and they were appointed according to need. Basically, the *Mirab* and subordinates' services were entirely paid for by stakeholders proportionately based upon their share of the river (Mahmudian 1969; Hossaini 2006; Eslami 2010) and historically, the states and central governments rarely directly influenced river management (Hossaini, 2006).

4.5. The Mirab Company; the outcome of hydrocracy

As a major legacy of the Land Reform Act of Iran's White Revolution (1962-66), large farmlands were divided into small pieces to allocate 'justice' to a whole range of the peasants to free them from the *Kadkhoda*[31] (literally village elder/hamlet master) –an actor who assembled the *old Mirab*'s selection procedure accompanied by farmers and a state representative. Such reforms forced the government into the mission of developing the hydrosystem. Reformist-modernist thinking changed the way of Iran's hydrosystem development for the sake of gaining more efficiency, and the holistic order of the old *Mirab* system gradually ceased (Balali 2011; Molle and Mamanpoush 2012; Harris 1953).

As mentioned before about Iran, the contemporary water abstraction system of *Zayandehrud* is based on technocratic expansion plans using exploitation contractors such as the *Mirab* Company. The *Mirab* Company was founded in 1993 according to the Companies Registration Act, enacted in 1936, essentially for maintenance. Figure 12 lays out the hierarchical system of the company. Its

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[30] کشیک

[31] کدخدا

structure is matched to what is laid out in the Commercial Law and based on a classic bureaucratic structure where the board of directors, Chief Executive Officer (CEO) and many liaison officers work to achieve the organizational objectives.

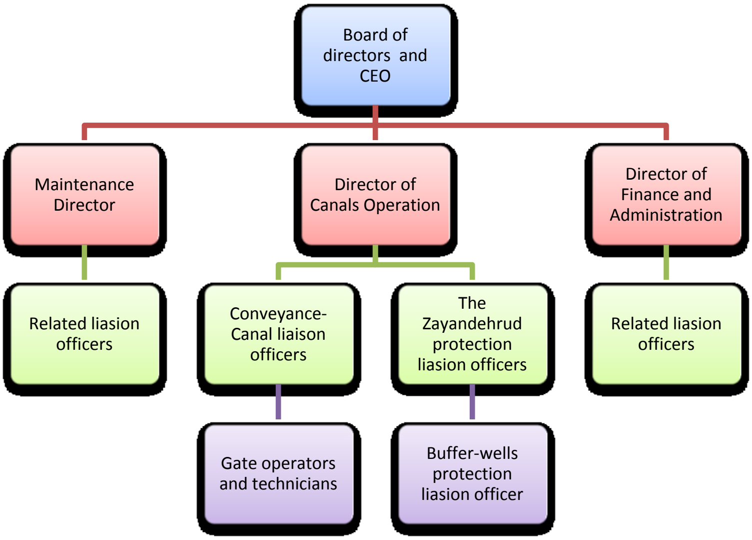

Figure 12: The top-down and hierarchical system of the *Mirab* Company

Figure 13 also shows the position of the new *Mirab* in the up-down administration system of the *Zayandehrud* River. As a quasi-private company it (was) is preferentially contracted by the government to fulfil the policies relevant to water apportionment in the Zayahdehrud River in an authoritative contract with the Esfahan Regional Water Authority (ERWA). Such primacy placed the company on the front line to implement the client's desires. Therefore, the *Mirab* Company is openly linked to the government; the money which fuelled the *Mirab* comes from industries, government and not from the local users linked to the societal classes. Looking at the terms of the *Mirab* Company's contract also reveals how the tasks and responsibilities of the old *Mirab* are being transformed and downgraded to those of a maintenance contractor.

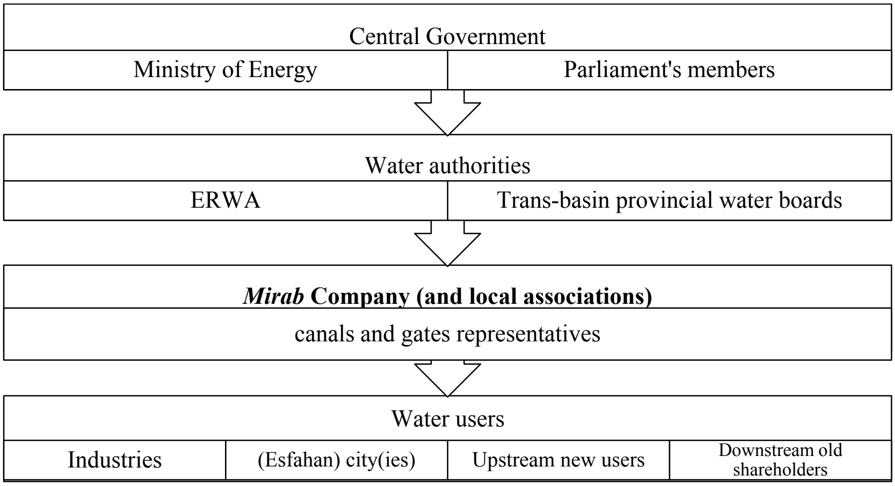

Figure 13: The up-down administration order of the *Zayandehrud* River

The *Mirab*'s model of water distribution was previously based on the *Maadi* and share rights; however, modern canals have superseded the *Maadi's water right* and shaped new rights for such recent shareholders/hydrosystems. These rights are annexed to the parcels that were 'originally irrigated with the old systems' (Hoogesteger van Dijk 2005). According to Iran's Law for Fair Distribution of Water (ratified in 1983), agrarian water rights are determined by the water needs of cultivators. Water scarcity and the river over-commitment have forced the ERWA to change the (amount of water related to) rights which should be allocated to the different outlets.

These sorts of fuzzy decisions (Molle and Mamanpoush 2012) have been made in the closed circles of the political classes (lack of transparency) and shareholders are narrowly involved in the courses. However, the *Mirab* and ERWA always claim that all outlets are equitably shared during drought but the rich actors such as 'factories have in general no problem in getting supply from irrigation canals since their demand is allegedly limited and the Ministry can sell water to them at a *much higher price* [emphasis added]' (Molle and Mamanpoush 2012).

For example: newly created amorphous water rights (the upmost users) and the manufactured waters that had already been sold out beforehand, has inch by inch changed a license or temporary permit to a 'right', and as a result, a source of conflicts. Moreover, there is no clear definition about rights and shares particularly during the droughts, either in the *Mirab Company* or in the law. As such old right/share/smallholders always complain about these new water rights because they are not well-defined in such newly founded processes.

Interviews and discussions with the staff of the *Mirab* and other stakeholders by Hoogesteger van Dijk (2005) and Payandab (2009) have resulted in some noteworthy points, such as, notwithstanding the law and the contracts, water rights are not volumetrically defined and are left mostly to the *Mirab*'s discretion depending on water released from reservoirs and the amounts allocated by a new founded committee known as the Crisis Committee.

As water volume distribution is safely in the hands of the *Mirab Company* and realising water volumes from the artificial reservoirs in the upstream are completely governed by the government, the user rights of outlets and individual users are thus subject to the decisions taken by the *Mirab Company* and the government. The *Mirab Company* is deemed as a manifest of the government's governance that has reduced the early/old water rights from different outlets to build new rights in exchange for distrust.

4.5.1. Reforms, dealing with conflicts

Moném (2002) has assessed the *Mirab Company* as in the top three of the most successful water-related agents in Iran[32] in relation to the other major exploitation companies. However, the existing conflicts show the evidence that we can doubt this argument because even industries and Esfahan City (two consumers whose use is increasing), as well as old downstream right-holders/users, are objecting to the unfair allocation of water and perpetually blaming the *Company* for imperfect distribution owing to their historical memory that is however replete with experiences of this type. 'Lack of control and precision in the distribution of water' (Salemi and Javan 2004) and after a relatively long experience of dealing with intricate socio-technical problems, three years after the start of the first severe drought (in 2003), the *Company*'s task turned to be more societal-oriented (Khorshidifar 2005) by riding on the country-wide wave of public participation. The directorate (including ERWA, see Fig. 4) of the *Company* justified the re-organization as somewhat of a flashback to sort through the old *Mirab*'s responsibilities. In line with new worldwide views, they aptly titled this collaborative approach to water management (Sabatier 2005) and deemed it as users' participation. The *Mirab* tasks remained just for the main modern canals and others were left out for Water User Associations (WUA) of local water users, which led to an improvement in some aspects (Khorshidifar 2005). By means of these reforms the *Company* outsourced its tasks in the second order infrastructures and direct communication with users to local and trustworthy associations. These associations also facilitated the difficulties relevant to 'trust building' between the

[32] Up to now, more than fifty companies such as the *Mirab Company* have been licensed by the Ministry of Energy.

two sides and undertook the responsibility of the contract because they are typified by trustworthy people. Reduction of the total cost (mainly owing to locals' lower wage expectations33) and performing minor maintenance are two advantages that the *Mirab* Company has attained by these reforms. Also there have been some improvements in terms of rehabilitation and renovation of aged canals and construction of many new ones, so the volume of water sold has increased and definitely has had an impact on the improvement of agricultural products (Khorshidifar 2005) albeit before the drought periods.

However, water users have still not fully had their expectations met in the fair distribution of water with such reforms. We specify a couple of reasons; firstly, the *Mirab Company* under the ERWB in many cases, even after the reforms, tries to decree the policies to the sectors. As the earlier examples showed this system painstakingly suffers from lack of transparency, a point that we are not sure that the reforms fully grasped as a value. Therefore the users and those who have the will to participate are still behind the schedule. Part of the problem is that the new *Mirab* has had substantial public participation in issues (after the reforms) where it would not use social power fruitfully.

Therefore following this incapability it cannot participate in the processes of conflict resolution as a mediator. Secondly, due to 'the overbuilding of water infrastructures in the river basin for extraction of surface and groundwater' (Molle et al., 2009b), there is no room to play with drought tensions and it has made new complexities for users, particularly downstream shareholders and the environment.

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[33] Contentment as a value for the locals.

4.6. A Water management evaluation model; the Mirab as 'Practice'

The previous sections described the tasks and responsibilities and also interests and conflicts of the old and new *Mirab* systems. In the case of tasks, moving from the old to the new *Mirab* implies subverting the traditions of water apportionment in our case study. Therefore, understanding this deformation and transformation of the *Mirab* – as an action - and its governance culture means understanding how one of the 'key individual and collective water management practices' (Thomas and Ahmad 2009) has altered or revolved over time. In doing so and to go through the evaluation model we consciously continue to limit the discussion in the next paragraph to our two actors' tasks to ask a few intake questions, mentioned in Table 5, about the primary and detailed tasks of both the *Mirab* systems.

The focus of the overlaid-by-the-rights old *Mirab* system was mainly – but not limited to - water distribution, primarily, collectively and individually as well as maintenance of the whole technical parts of the river system. Water apportionment was implemented according to the *Blouk*s' water share which stemmed from *Sheikh-bahai*'s edict. We see conflict resolution measures and remedies (precautionary role) in the secondary order of tasks in which the old *Mirab*'s governance pattern was questioned because its system made massive endeavours to boost courage, liberality, temperance, truthfulness, intellect and benevolence.

As our previous descriptive arguments showed, this is totally dissimilar from 'command-and-control' (Schoeman and Allan 2014) and the centralistic capitalized modernist governance of the new *Mirab*. The old *Mirab* steered others according to its foresight and flexible skills and has been known as a mediator who would enter into water disputes accompanied by the hamlet's elders and warlords. The old system also performed a supervisory and inspecting role to avoid unauthorized water abstraction, repeatedly concomitant with locals. All these measures and mechanisms worked for the fair distribution of water, autonomously.

The primary task of the *Mirab* Company is maintenance by predominantly technological means in line with the state's on-hold and behind-closed-door approvals. This is the reason that the new *Mirab* is a remarkably time-consuming and over-formal institution (Schoeman et al. 2014; Engle et al. 2011; Pahl-Wostle et al. 2007). In sum, it is apparent that the *Mirab* Company as a modernist system is responsible and economically speaking affordable but cannot particularly deal or exchange with the users. Because the previous local and dynamic water apportionment system was replaced by a remote control (gates and regulators in term of technology and out-of-basin opinion-making in term of policy) and a robust system. Unlike the *Maadisalars* - a *Mirab*'s subordinate, responsible for *Maadis* and *Keshiks* (overseers) - in the *old Mirab* era, now the gate operators have replaced the *Mirab* and we see that the concept of 'technology's in-betweeness' (Floridi 2013) is playing a crucial role because the gates and 'state-appointed' groups/persons (Molle and Mamanpoush 2012) have been placed between the *Mirab Company* and the water users. In such a system, technologies (i.e., gates) are placed in between a human system (the *Mirab* Company) and other human society (shareholders) (Floridi 2013). Now it seems that the *Mirab* Company is attuned well with two of Ellul's 'five specifications of technology': it has autonomously developed, and is automatically operated - independent of its surrounding society.

Table 5. Intake questions for theoretical framework

Questions about	Old *Mirab*	*Mirab* Company
Primary tasks and responsibilities	Governing and mastering the river's society as well as maintenance and apportioning of water (mostly by local representatives)	Controlling and protecting the government's right-of-river Maintenance Data acquisition
Secondary and tertiary tasks and responsibilities	To prevent conflict Fair distribution of water	Market- and technology-oriented mechanisms of water distribution based on the clients' desires (calling for and collecting the water fees based on agreements and contracts)
Subordinates and employees	*Keshik*, *Maadisalar* and villagers, appointed temporarily for a specific purpose. Not formal employees.	*In situ* companies have been recently added on the contractors' side to avoid one-by-one contract mechanisms. Formal employee mechanism based on a FT contract system.

So far, this chapter has explained about the right and the wrong aspects and informed us about the tasks and the issues of our cases, but not the reasons. We have shown true and false evidence to provide our descriptive claims. So what it is missing here is defining a model that implies some actions. In the next sections we will try *to move from descriptive claims through normative claims* to make some recommendations based on the analysis and the conclusion.

The theory of 'practice' was proposed by Alasdair MacIntyre in 1981. He developed a theory of social 'practices', which in standard philosophical parlance defines a meaningful coherence of human actions through certain 'values':

Any coherent and complex form of socially established cooperative human activity through which goods internal to that form of activity are realized in the course of trying to achieve those standards of excellence which are appropriate to, and partially definitive of, that form of activity, with the result that human powers achieve excellence, and human conceptions of the ends and goods involved, are systematically extended (MacIntyre 1981: 175). Examples of such activities can refer to engineering or a club's membership or being an elder who has an extensive role for *Mirab* selection with the specific ultimate goal which could be food security, joy, welfare, making good investment, Maslow's hierarchy of needs and etc.

It is not coincident that, MacIntyre, in his book After Virtue, has introduced himself as one of the ethicist and social thinkers that have profoundly and controversially stood vis-à-vis of the current modernism ethos of liberalism, (Legenhausen 2005). We applaud MacIntyre and Legenhausen who trace the injustices of modernist thinking which originated in the Enlightenment. As Ronald Beiner (1992) observes, 'What makes MacIntyre unique is that for him the problem is not merely individualism or liberalism but modernity as such.' He has criticized the individualistic and liberal ethics and reappraised whether normativity is '*inherent*' to practices by referring to 'internal goods' (Jochemsen and Glas 1997; Jochemsen 2013; and Van Burken and De Vries 2012). Normativity of rules and their related norms of individual or collective professional actions should be shaped in advanced, because these actions have inherently normative aspects (Jochemsen 1997). The main goal is to develop an approach in which 'normativity' is seen as intrinsic to different practices (Van Burken, and De Vries 2012: 137). In this thesis we adopt the model of *Normative Practice* as developed by Hoogland and Jochemsen (2000, 2006 and 2013), Van Burken, and De Vries (2012). They initiated their theory as a response to the difficulties that they, as medical practitioners and military commanders, had been respectively practising with translating such rules and obligations into their research's practices.

For example, consider a factory with a subdivision that has been committed to respect nature and therefore has as its ultimate goal: environmentally friendly products (this is what we called 'direction'). If it has a division for pollution control (that is part of the company's 'structure'), that fits well with the direction of the factory. This means that the direction and structure of the factory fit together well and that the practice – carrying out environmentally-friendly production - is performed without conflicting norms. However a problem could occur when the factory's ultimate goal or highest value is 'respect to the nature', but structurally there is no single related department, ; in other words, the direction and structure of the factory are going to contradict each other.

So obviously we can predict that production or entrepreneurship in this factory would not be carried out and developed (reached its goals), because its structure does not match properly. If another practice is included in the example, say the government as a practice that has a strong interconnection with preserving for nature, the role of normative practice in our accounts will become clearer. Suppose that the government's highest value is also preserving nature and if every organisational procedure is aimed to roll up wealth (economic aspect or benefit), then the practice will not reach its goal. Sub-practices of such practices of course have their own relationship with each other to make development; either they work or they fight but all these actors somehow deal with each other. So in the ideal situation, the government (as another practice or sub-practice), industries and customers all agree but all have the same set of purposes and they will all have a set of structures that fit well together.

They still have different structures because the government has different responsibilities to industries; the government has responsibility to legislate to set laws that others are never allowed to do. Each of these actors contributes in his own way. They have different responsibilities but should all fit with a common direction. Thus in general, the practices' structures are characterized by the rules and norms for the actions taking place. This defines the 'normative practice'. Indeed, they depict the practice while also being the performance bounds of a practice (Van Burken and De Vries 2012: 139). What a practice aims for is also included in its structure. Before analysing the *Mirab*'s practice, we are about to describe the details of the theory. First, we start with the structure. Jochemsen and Glas (1997) distinguish three sub-types for a practice's structure (constitutive rules); '*Qualifying*', '*Foundational*', and '*Conditioning*' rules (Fig. 14).

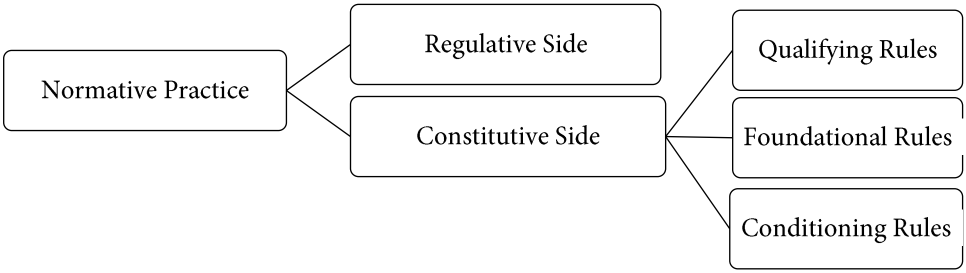

Figure 14: The normative structure of a social practice

4.6.1. Qualifying rules

Qualifying rules are related to the main task of the practice (in the case of the Mirab: distributing water). For the appropriate distributing and apportioning of water the *old and new Mirab* practices needed and need economic activities as goals to survive. Obviously the questions are in which boundaries and what situations can a *Mirab* system take over the edict (old *Mirab*) and approvals (new *Mirab*) to execute the rules? Whose justice is allowed in which case? These questions directly refer to the objectives that a practice needs to respond to in order to qualify as a normative practice.

For describing the *qualifying* rules, we go back to the military practice of Van Burken, and de Vries (2012). In the military practice, force should ideally be used within the global regulations of war, in order to promote justice. For example, take 'shooting' itself; it does not make sense to see someone as a soldier; a soldier is in the first place someone who is in service to promote justice and is therefore allowed to shoot, under certain (legal) conditions. In other words, insisting on following legal boundaries is the main message of this statement. Thus, the *qualifying* rules are those rules that define the ultimate destination of a practice. These rules *are the* *guidelines and right paths for achieving the ultimate goals*. The qualifying rule stands at the top of all the other structural rules, norms and principles and it is the guidance for the qualifying aspect, and therefore we mark it as important in our future discussions in this chapter.

Jochemsen (2006) holds the notion of 'goal-rationality' to indicate that professionals should look at the *Telos* as a foundational not qualifying rule. He warns that the formulation of rules and principles needs to be typified by uniform patterns of reflection and interpretation because societies are changing and practices are developing (Jochemsen 2006: 108). This process is very consistent with our account in transforming *Mirab* thinking from holistic to modernism. The primary process of the old *Mirab* practice is about promoting the distribution of water with the confirmation and approval of the indigenous people and leaders. Therefore the *Mirab* practice should be characterized as by an impartial person tasked with achieving the fair distribution of water. The new Mirab has a capitalistic view on water as a rare and profitable good. That by itself has shifted the company to act as a sales agent (of ERWA) instead of having the distribution of water as a main task. However, the *Tumar* is an accepted and well-known set of guidelines for the whole *Zayandehrud* practices as well as the Mirab Company, though. Nonetheless, the foremost customers such as power plants, steel industries and refineries - and of course those posed the bargaining power of political circles- have made the company sceptical of being able to perform the edict's rules, comprehensively.

4.6.2. Foundational rules

Foundational 'rules prescribe the activities that give a particular practice its characteristic content' (Jochemsen 2006: 105). According to Van Burken, and De

Vries (2012), Searle (1969) explains the chess metaphor to explore rules' boundaries of normative practice. Using that, *foundational* for the game are those rules that explain 'how the pieces are limited or licensed to move on the board'. They are *foundational* because the game was based on such rules. If the rules change, intentionally or unintentionally, 'we can no longer speak of the game of chess (but perhaps of a different game)' (van Burken and de Vries 2012: 139).

The *foundational* rules of the *Mirab* are referred to: how and what knowledge and skills are needed to fulfil the *Mirab*'s obligations? Therefore, the *Mirab* 'as a social structure entails the effective utilization of [… water] and technical means' (Jochemsen, 2013) in the process of other practices'. For the Old *Mirab* practice the *foundational* rules are the methods that are adopted to perform and implement the *Tumar* orders, such as: the personage of *Mirab* to steer and engage trusting subordinates, well-accepted and religious-based rules of mediation of conflicts and running a constant rate of water when the river hits a drought or a flood. However, for the *Mirab Company* there are laws and approvals in which the company can manipulate the rules and/or put restrictions on them. The distribution system is entirely physically in the hands of the *Mirab Company* although the government also pushes the *Mirab Company* not to deal with the riparian societies and farmers, because such rules and approvals are not very transparent or accepted.

4.6.3. Conditioning rules

The *conditioning* rules 'formulate conditions that should be observed in performing a practice, but they neither define the "technicalities" of the practice, nor its finality' (Jochemsen 2006: 105). In the case of the *Mirab* practice, these are, for example, sociotechnical- and economic-related norms that limit the practice. A well-accepted and -derived base could be an appropriate base to describe conditioning rules in the old *Mirab* system. The *Sheikh-Bahai* edict was – and we claim still is - a comprehensive deed that encompassed both conditioning and foundational rules. No amounts of water could be diverted without the edict's license. The river was conditionally diverted by a few multi-task dam-bridges and distributed through channels, *Maadis* under the *Tumar's* prescriptive chapters (Mahmoudian 1969). These barriers/bridges diverted water from the river and coupled the societies on both sides of the river. The latter function has still continued.

In fact, the following questions elucidate the conditioning rules of the Mirab:

- what are the *Mirab* incompetence indexes – on which criteria could he be refused by those who vote for him?
- who are the responsible persons and for what matters?
- when should water be released through the channels?
- who should pay and be paid – wages and paying mechanisms?
- who is eligible to vote for the *Mirab* and what is the selection mechanism?

Nowadays, some of the concepts of the *Tumar* still refer to the new *Mirab* system, albeit not the main one. *Conditioning* rules are related to water laws that are enacted by the government. In our particular case the rules are also under Sharia, as *Iran's Law for fair Distribution of Water*[34] is linked to the religious fiats. Parts of the *Tumar* are infrequently executed but as minor documents. Under certain 'conditioning' rules, the *new Mirab* system is directly supervised by

[34] Iran's water-related laws have been changed by frequent but irregular local and national approvals, over the past decades.

government. The rules are inspired by what Heidegger named 'calculative thinking' which lead to an ideology of efficiency, and therefore water ought to be managed by gates for more affordability. Now the technology tries to bridge the gap between society and the *Mirab*. Water could be apportioned according to government approvals which are enacted and executed in fuzzy ways.

4.6.4. The directional side of Normative Practice

The *direction* recourses to the *regulative rules* of a normative practice. It is about the more profound values that are needed to 'competently perform practices' (Jochemsen 2006: 107) in difficult situations (Jochemsen 2013). These regulative rules imply an existential dimension of goods which are internal in life and 'directs existential choices about good and evil' (Van Burken and De Vries 2012: 140). They involve the different basic beliefs that stimulate people to accomplish 'their tasks in different practices or the *ethos* of the profession. This affects the way in which rules are interpreted, positivized and developed in everyday practice. It refers to the set of worldviews, beliefs and motivations that steer the action' (Van Burken and De Vries 2012). Many examples can be provided; take playing with children, 'not to play too harsh' or 'to let them to win' are directions of a normative play. Actually, by using these ways to play the children do not alter the games' structure, but instead apply the rules in a specific way, expressing the strategy itself. A possible direction for the water management practice is, for example, ways to apportion water fairly in different circumstances such as floods and droughts or winning the hearts and minds of the locals by participating in the process and addressing the values of the river, water, ecosystem and environment. As we mentioned earlier from Molle and Mamanpoush (2012) who quoted from Spooner (1974), the *Mirab* 'must prevent the powerful from trespassing on the weak with regard to the shares of water' and mediates water disputes 'with the confirmation and approval' of the local leaders. The underlying worldview here is that water is a common valuable entity and should not be sold. This view was fully accepted and performed by the directional side of *Old Mirab* practice.

It is important to note that, in the concept of 'normative practice', the 'normativity' is not only located at the regulative side but also at the constitutive side. Practices are not neutral in that which defines them; there is a normative element in the structure itself. In other words, practices are normative both in what constitutes them as well as in what regulates them. One is not as free to perform actions within a professional practice as one is in the 'private' realm.

4.7. Analysis; How potent is the Normative Practice idea in the Mirab practice?

The tension between the rules and the degree of freedom and responsibility with regard to the interpretation of the rules is conceptualized in the concept of a 'normative practice'. The well-functioning of a 'practice' requires that it simultaneously observes a constellation of, among others, the normative principles related to the aspects mentioned above (Jochemsen 2013). For the purpose of this chapter, understanding the deformation and transformation of the *Mirab* as a normative practice and its culture means understanding how one of the key individual and collective actors of the river management has altered and revolved over time. Referring to the texts we can put simply that the old river management practice had in fact a team leader who used leadership skills to carry out the actions related to the distribution of water in forms of physical dimensions, socio-technical contradictions, conflicts and even controversies. The notion of 'internal good' of this normative practice is also targeted by the promotion of 'justice' referred to as a directive rule. Admittedly, it was not merely obliged to steer others just for profitability or to make money. His (her) primary function (Table 6) was 'founded' as a distributor by the *Tumar's* technical chapters. Following that therefore his (her) organization was allowed to conduct its '*foundational*' rule based on a set of sorts of 'conditions'. It was conditioned by a handbook named the *Tumar* and physical boundaries which were bounded by *Boluks*. Apart from technical norms, he carried out his obligation on the framework of economic, social and even ecological norms. The rules did not alter even in drought conditions because there was always room to play with extreme events. Under the *Tumar* (s)he allocated water and was paid proportionally by users (Mahmudian 1969), and there was no need to call for water fees or contracts. Molle and Mamanpoush (2012) also acknowledge this about the whole governance in the *Zayandehrud* even in the lateral valleys: 'managers were paid by users, proportionally to the amount of water received, and were dispensed with if their service was judged to be unsatisfactory.'

In the new ways of thinking the *Mirab* Company should be 'qualified' to achieve a high profitability. Founding the *Mirab* Company structure based on such a qualification caused it to gradually tend to disregard traditional ways of thinking and to become an up-down system. So in response to the question in the introduction, now the perception is that the ultimate goal of the current flow of processes inside the *Mirab* Company – as a practice - is to please ERWB. Based on the *Company's* contract (2010-2013) just 25% of the total *Mirab*'s tasks are relevant to management and the others are mostly relevant to maintenance and providing machinery. The last section also infers the type of objectives for this practice: operation, maintenance, and guarding services. As we described earlier Moném (2002) has acknowledged that the *Mirab* Company holds a high rank among other active exploitation companies, but the overwhelming contradictions have shown that there is a strong necessity for transformation of the way of thinking and this should be sorted through an attuned cultural-societal system to achieve a fairer distribution of water (Salemi and Javan 2004; Harandi et al. 2014). Although it seems that the new *Mirab* practice has tried to reshape the ultimate goal by reforms, yet the tasks and the system are reluctant to take distance from state-centred modes and orient themselves on the old *Mirab* merits and values. One may claim that without the Mirab Company it would certainly be easier to distribute water in *Zayandehrud* and it is a price well worth paying. We cannot totally stand against the new *Mirab* system and its related values. Economy and efficiency are essential values nowadays but it is not to be considered as *goal* in the *qualifying rule* (Jochemsen 2006).

Before coming up with the final epilogue and to show how the middle column of the table reflects a holistic approach and the right-hand column displays a modernist approach, Table 6 depicts this summary, because this is the central message of the chapter.

Table 6: Epitomised rules of *Mirab* Normative Practice

Normative Practice Rules	Old *Mirab* Practice	New *Mirab* Practice
Foundational	The rules related to skills of water management in semi-arid areas for the *Zayandehrud*. Such skills that the old *Mirab* can implement the *Tumar* technical chapters including: - allocation, apportionment, distribution and regulation of water in the normal river flow - management of the river rate under extreme events - droughts and floods - mediation of conflicts - appointment of subordinates	The rules related to skills of maintenance according to world-wide standards. Water should be managed by an enterprise company, efficiently based on: - allocation, apportionment, and distribution according to what amounts of water are available in the upstream artificial storage - carrying out maintenance services of the gates and canals according to global standards of hydraulic engineering - managing the river rate in the case of extreme events - droughts and floods - with incomplete decisions - no mediation role in the conflicts - subordinates are the engineers and technicians, sometimes coming from remote areas

Table 6 (continued): Epitomised rules of *Mirab* Normative Practice

Normative Practice Rules	Old *Mirab* Practice	New *Mirab* Practice
Qualifying		Hydraulic Mission Water privatization
	Must prevent the powerful from trespassing on the weak with regards to the shares of water, and refereeing water disputes with the confirmation and approval of the local leaders so that the *Mirab* practice is characterized as an impartial person for qualifying the fair distribution of water.	Must build powerful networks with political circles for gaining higher benefits, a capitalist view to see water as a 'good' and users as customers; those who pay more money have priority. However, it has accepted traditional water rights although there are demands such as the city, steel industries and refinery but the products are too 'strategic' to be stopped

Table 6 (continued): Epitomised rules of *Mirab* Normative Practice

Normative Practice Rules	Old *Mirab* Practice	New *Mirab* Practice
Conditioning	Handbook: *Sheikh-Bahia* edicts (*Tumar)* Physical dimensions: seven *boluk*s (districts) linked to the land Staffs: - one river headman (*Mirab)*, elected by the hamlet's elders[35] in association with a state representative[36] generally from the middle reach of the river. - seven *Boluk*s representatives appointed by stakeholders from the community. - thirteen *Maadisalar*s (managers of channels) and a lot of *Keshik*s (temporary overseers), appointed by the *Mirab*.	Handbook: State approvals, discretionary power of government, parliament members and political circles over water allocation. Physical dimensions: Whole of the river and the main canals of 5 new irrigation networks (no straight link to the hamlets) Staffs: uncertain depending on network but generally there are at least one engineer, one technician and three *gate representatives* (combining tradition and modernity).

[35] ریش سفید Rish-sefid

[36] قاصد Ghased

Table 6 (continued): Epitomised rules of *Mirab* Normative Practice

Normative Practice Rules	Old *Mirab* Practice	New *Mirab* Practice
Conditioning (continued)	Economic norms: *Mirabs* were paid by the water-users.	Economic norms: qualified, chosen and contracted by the government.
	Social norms: *Mirab and subordinates* were voted for and supervised with annual ballots by users not the state.	Social norms: local partners are responsible for the canal's hydraulic gates (representatives for the gate). The priority of water allocation are firstly the city dwellers, then the industries and finally the agrarian users, provided there is any left.
	Technical means: a few multi-task dam-bridges; water diversion e.g. *Maadi*s (channels) for conveyance and distribution; facilitating society's connections on both sides of the river.	Technical means: autonomous technological artefacts (diversion dams and automatic gates).
	Ecological norms: extraction of the water in the river should be restricted to just 165 days a year (6th June-21thNov).	Ecological norms: extraction of the water in the river is restricted for the whole of the year and water is only released from the upstream reservoirs according to state approvals.

Table 6 (continued): Epitomised rules of *Mirab* Normative Practice

Normative Practice Rules	Old *Mirab* Practice	New *Mirab* Practice
Regulative / Directional	Water is to promote justice. Taking justice as its direction, the other values are categorized under it as a pillar of virtue ethics: Kindness and gentleness Living with the nature not against it. Water is a right not a commodity to sell and buy. Water is a socio-ecological asset. Autonomy Democracy Societal integrity Individual and collective frugality	Water is central for economic production. Taking benefits and economic values as its direction, the other values is categorized under it as a pillar of capitalism: Entrepreneurship Technocracy and hydrocracy Efficiency

In Table 6 I have shown the evidence that displays the modernist characteristics of new *Mirab* practice and the holistic approaches of old *Mirab* practice.

Starting with the *foundational* rules, periodically-issued approvals incorporated with a purely engineering view of the new *Mirab* stemmed with scientism, are compelling evidence for the *Mirab* Company to encompass modernist thinking and a utilitarian engineering system. Consequently, it puts individuals in the centre (e.g., a CEO or the company board), and fosters the upscaling and unification –two distinctive characteristics of modernity- to challenge and increase efficiency. However, in contrast, it is part of the old *Mirab*'s image to offer guidance to connect and to induce the social meaning of water in its team and the surrounding society. His capability was in line with the holistic orders of actors in the old *Zayandehrud* management system (Fig. 15).

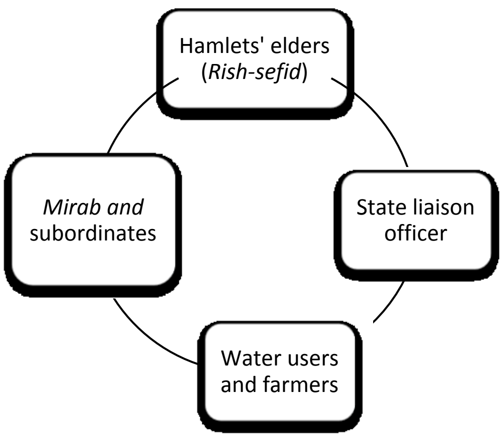

Figure 15: The old *Mirab* structure; a holistic order

By using the *qualifying* rule, the ultimate goals of the practices was revealed. The new *Mirab* in fact has taken the economy as the centre of its ultimate goal and puts the users/farmers mostly as customers which should be contracted. These obviously do not belong to a holistic system. The *Mirab* Company is focusing on economic values – i.e., to become an up-to-date maintenance company - as its ultimate goal, so it needs to see water as a good. Such capitalism-modernism thinking never brings justice - or welfare - for the users because it should be more respectful of the client's desire instead of the users' need. The old *Mirab* was committed to constructive engagement within the water cycles and to social relationships. Interaction on an equal footing with the water users was key to achieving shared objectives for justice. This holistic thinking made him an autonomous and trustworthy manager to rule the system.

We claim that the *regulative* rule has meticulously explained the inherent values of both practices. The new *Mirab* – as a result of the hydraulic mission – is trying to win the heart of the client, instead of water users. In addition to efficiency and machinery-oriented management, the *Mirab* Company has adopted new norms such as entrepreneurship, after the recent reforms. The latter is a value which was within the old *Mirab*'s holistic thinking as an internal good. In the *Mirab Company* no one is responsible 'to please the user' but the direction is 'to respect the user's demands'. Obviously, a practice has to confront the rules (structural and directional) that are barriers to fulfil the responsibilities and will not reach its goal (which sounds appropriate) if its structure would not fit with the goals. As listed in Table 6, for the old *Mirab* a composite range of values – mostly in the virtue ethics context - can be enumerated, from kindness and gentleness to frugality and we argued there are unavoidably no synonymous indexes in the new *Mirab*.

4.8. Conclusion: a newer Mirab practice

Water-management practice is not merely a collective function but is a well-defined social activity which entails that this practice existed before we enter into it and change its norms. For all of the norms, with the *Mirab* analysis in the distribution of water, we elucidated their distinctions as a 'normative practice' according to the rules and laws which have already insisted on a specific norm. The normative practice idea also helped to define what way of thinking and what degree of skills and tasks (e.g., tasks which are based on hydrosystem development) belong to the water management practice. The idea appropriately depicts a map and provides a way of thinking for (water) professionals to show their concerns with regard to developments that directly affect their practice, e.g. decisions related to allocation and adjustment of released and diverted water during drought periods for different area and various purposes. The chapter argued how one 'normative practice' transforms from a holistic version to modernism in a historical time line, a shift from one Normative Practice to another Normative Practice, in fact. We also argued that the new *Mirab* system is a controlled base system with a modernism ethos that can result in a clash between the 'structural' and 'directional' rules inside such normative practice.

To discuss the implications of the aforementioned analysis and to realize that how the alignment of the practices should be proposed, this conclusion needs to interpret the direction for a 'newer' *Mirab* practice and the institutional/governance structure put forward. As it is presented in Figure 16.a, the norms and standards of the Mirab Company are swimming around and are not reflected into the shareholders' value (the *Company* sees them as customers). The arrows show that the direction of the *Mirab Company* is not aimed to respect shareholders' values. It clearly implies anisotropy between *Telos* and direction(s). The *Mirab Company*, now- having more interrelation but still trying to push the norms and values into the users' society. The *Company*'s reforms (Fig. 16.b) have directed the current system to change certain values, but to change the overall trajectory of that is another structure. The outcoming tension between the old and *new Mirab* systems which we analysed does not belong to the systems they have, rather it is a consequence of the two completely different value systems. The *newer Mirab* should be more integrated and coherent.

The *old Mirab*'s investigation analysis showed how the structural and directional rationality of a holistic water management system can bring reasonable concordance between water and surrounding societies in the case of 'justice'. As such we can model on from the system such direction and structure over the *newer Mirab*. The arrows reflect the correct performance and as shown in the figure 16.c, the pace and reflection of performance of the *newer Mirab* normative practice must be mutual and reciprocating with the society. To revive the *old Mirab* values, the boundaries also ought to be reworked and the decisions should be taken in a more transparent way.

We have seen the *Mirab Company* as a sample in the field, which is 'chained to' the technology rather than directing communication with water users, and as Heidegger discussed, 'we can be freed from this bondage by adopting new ways of thinking' and 'a co[-]evolutionary path to the future', and a way which sets a precedence and can increase the values of traditional hydrosystems (Harandi and De Vries 2014). However, we cannot go back to the old system. Broader values and norms should be included, *in fact back to the old revised system in term of values and merits* which openly interacted with the water context (and society) norms and standards, and at the same time it would maintain its own configuration (see figure 16.c). Modernist (hydro)systems are swimming around (Fig. 16.a), based on the liberalism ethos by means of enterprise routes to sustain it; but indeed, this is a kind of development trying to sustain among the Hydraulic Mission which dictates what has to be done. Subverting the modernism does not mean that we should turn our back on the advantages of modernist relevant to culture of governance but sometimes it is necessary to look closely at the rules (of development) within the involved practices and make sure they makes sense when they interact with the society. Further, the modernist thinking to achieving environmental and social developments will require significant contributions from philosophy and social policy (Schienke 2012) and will need to challenge this question 'Does mastery of technology ensure abundance?' (Nye 2006: 87).

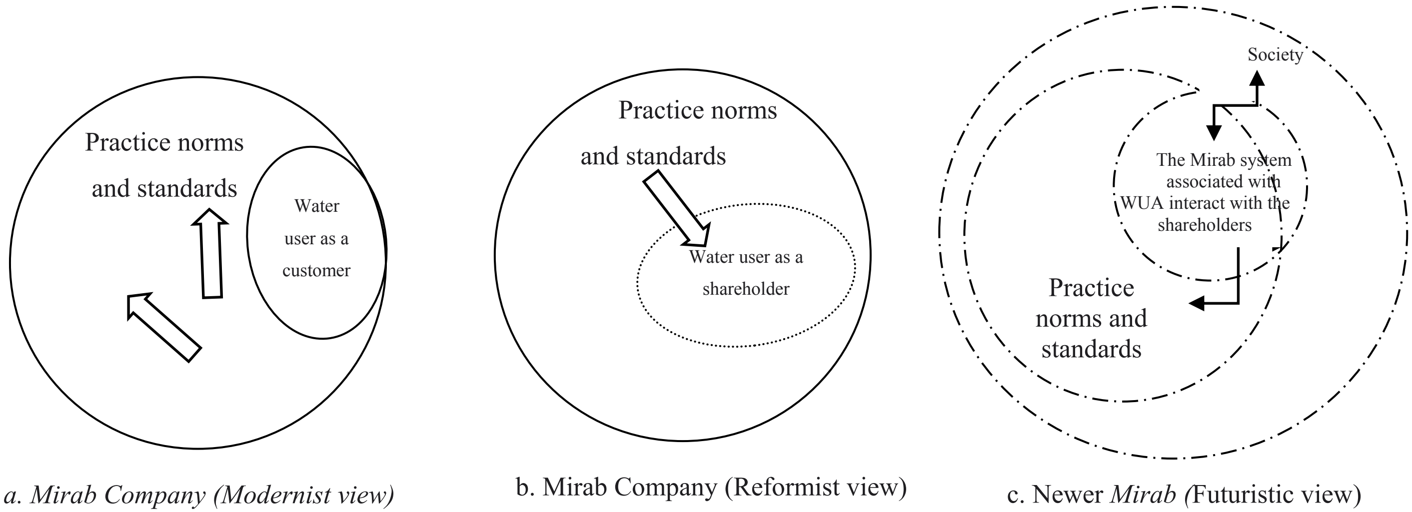

Figure 16: The desired *Mirab*'s ways of thinking

However, the *Zayandehrud* hydrosystem has the normative practices that at the same time are helped by other assorted practices. The idea is clearly able to contribute to exploring capabilities, relationships and achievements of different and diverse related parties that might have different interests. We propose to research the usage of the concept of normative practice to account for the whole *Zayandehrud* systems' practices in the next chapter. In a more profound view, normative practice can be considered for analysis of sub-practices, some of which are maybe part of the others or are juxtaposed. Aside from the *Mirab* practice, which we described in this chapter, the government, the farmers and the engineers can also be labelled as practitioners of normative practice. They all have their own rules but they all somehow have to interact with each other. Thus if they all have to cooperate during the hydrosystem's development, the rules can clash if each practice has different rules. This is a socially established complex of related actions, due to different practices working or sometimes clashing together for which a characteristic pattern of norms holds. Engineering consultancies and safety and risk institutes for instance, often deal with very specific issues in the complex relationships between the interests of engineers, policymakers, the boards, and the state and local authorities.

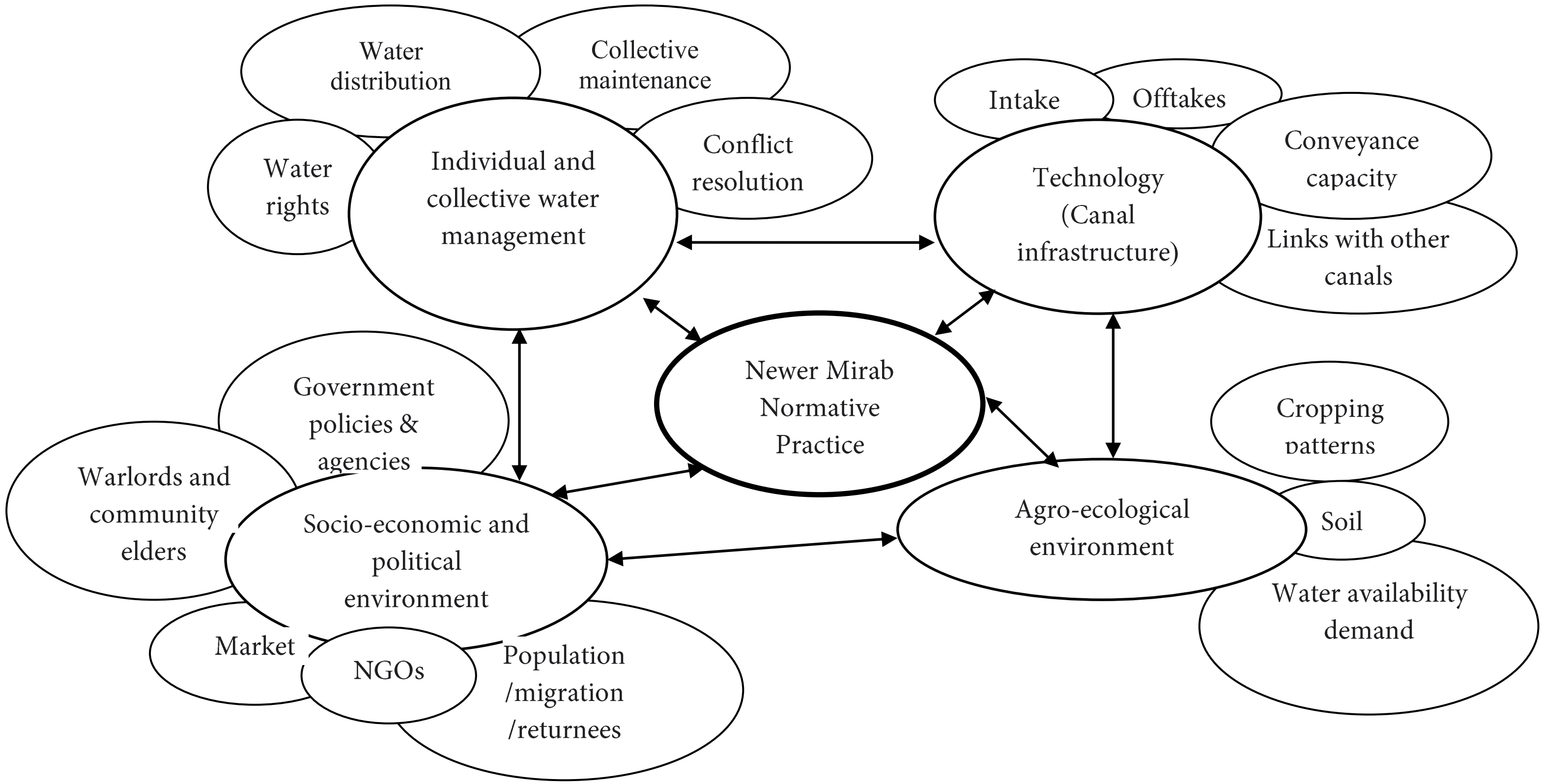

Figure 17: The holistic institutional and governance structure of the newer (desired) *Mirab* normative practice (The general scheme derived from Thomas and Ahmad 2009).

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He who searches for people's shortcomings should start with himself.
– Imam Ali (AS)

CHAPTER 5

Hydrosystems as Multi-Actor Phenomena, the Zayandehrud River Case[37]

[37] A version of this chapter has been submitted to the journal of Contemporary Water Research and Education.

Index Terms— *socio-technical systems, water governance, actors analysis, normative practice, Zayandehrud River, conflict and cooperation, conflicting values*

Just as in many other fields, water management's policy/decision-making operates accompanied by the concern (and concert) of different actors — individually or collectively, who all have their own interests (Bressers et al. 1995; Kickert et al. 1997; Hermans 2005). Recently there have been plenty of but not sufficient discussions to redraw the linkages between water, society, technology development, actors and governance patterns' issues. Amongst them we see Carroll's (2012) paper which has used the actor or stakeholder analysis as a tool to argue that actors are not entities to set apart from the environment, and another article that 'marches' between technology and society, to show 'they both shape and are shaped by' (Barnes 2012). This present chapter comes with new ideas to contribute to these discussions and other larger ongoing endeavours as it is more of an imperative than ever for us to be concerned with the norms, values[38] and responsibilities of actors involved in development processes.

Actors' relations, interests and values are often disproportionate to the socio-ecological mechanisms and interdependencies that exist in water management (Timmermans 2009). Take a complex river basin system in the remote peaks of Tibet or a delta area in the mouth of the Netherlands' Rhine; there are questions concerning water policies on how the policymakers match justice, societal and economical norms, ecological and environmental actualities and political realities with the tasks and interests of the involved parties (Jensen 2013; Harandi et al. 2015 & c; Zwarteveen and Boelens 2014) in this complex water network. We have no illusions about the discussions upon the multi-actor-systems analysis, but

[38] Everything without intention or will is a value. The environment, economy, wellbeing and health can also be a value.

discussions are still rare or non-extant and have often been confined by variables analysis, policy change and behavioural simulations and theories (Crosby 1992; Hermans 2005; Timmermans 2009). Therefore the norm-based interactive actor analysis is rarely considered in the analysis of water conflicts (i.e., in the context of virtue ethics).

The notion of conflict itself calls for much more work on what we shall label 'normative conflict resolution': the need for different methods that might be used to (re)solve or negotiate water conflict. However these are not discussed at full length in this chapter. Surely, a single article/research/chapter and one discipline cannot deal with all of them or explore the full range of the questions and concerns and make some of them redundant in this regard.

In this chapter, the *Zayandehrud* River case in Iran is at the heart of what we are trying to argue. However, the river as a debatable and drought-prone region (Harandi et al. 2014; Safavi 2014) is crumbling with growing numbers of conflicts over water. The ongoing conflicts have prevailed for years and unfolded in slow motion. Drought aside, the lack of comprehensive knowledge about interlocking water cycles, social capital, norms and goals were and are hitherto immensely important parts of the issue. We in fact interpret a lack of knowledge about the actors' norms and interests that are inconsistent with each other and a knowledge that links actors to solutions (Hermans, 2005:2) to learn how to be free of friction.

For the aforementioned purposes of this chapter, this quick exploration only serves to give a glimpse of how complex the conflict of the *Zayandehrud* is. On the one hand this chapter is a sort of painting to show all the various actors and on the other hand it shows how the norms of these actors conflict:

- The chapter wishes to start with a bird's eye view on the actors and moves onto the inside of the case study to show where the conflicts are. It will review each of the actors and describe what they look like in terms of values and norms, their different roles, tasks and responsibilities.
- In the next section it makes a selection based on an actor analysis to see who the most important actors are. Using the actor analysis (as our primary stage analysis) we can show where the ropes for pulling and pushing of the different actors are.
- Moving on to the main analysis, this has a philosophical approach that enables us to reveal the most important actors. We will perform this second analysis by means of a framework called *normative practice*, to make this approach clearer and more substantial. This is because by using normative practice theory's criteria we can compare different norms in the different actors that are conflicting. Normative practice theory and these articles[39] also illustrate how a hydrosystem is influenced by the actors as well as technology over time, externally.
- In the conclusion we will argue that such frictions are one of the causes that ultimately coalesce to sink (any) solution over water conflicts. Such conflicts are in the norms and happen not because of different values, but due to inconsistent *direction*.

5.1. The Zayandehrud, gripped by actor-made perils

In the grip of an extreme ongoing drought that began in 2000, it is further beset by human-made perils. The farmers of central Iran's Zayandehrud had no advance warning about this water shortage. As the drought continues, decision-makers have stressed the need for continued conservation, but projects for supplying industries and far-off cities with water from the Zayandehrud have nevertheless proceeded. Upstream (in the tributaries that feed the river), others took advantage of their bargaining power to obtain Zayandehrud water (Molle and Mamanpoush, 2012). The river's water rights-holders (mostly downstream farmers) only realized this

[39] Current chapter and Harandi et al. (2014).

when their share gradually started to go down. That was 2009, when the farmers concluded that the (water governance) system places all its structural inefficiency and bureaucracy on their shoulders. Despite numerous restoration schemes, the river and modern canals dried up; the farmers were unemployed, their livestock and equipment were sold, and acres of lands were left uncultivated. The groundwater conditions, if not worse, were no better than the river. For years, criminals had been stealing groundwater, which intensified the aquifers' depletion.

A quiet month in the Persian year 1391 (February 2013) witnessed an unprecedented dispute over river rights and shares. Downstream farmers on the Zayandehrud struck out toward the governor on their standby tractors and combines. To bring about change, they covered these tractors with banners: 'neglected rights ought to be mooted,' 'who is taking our water rights?,' 'traditional water rights are our ancestral heritage,' 'revive the Zayandehrud.' They tried to stir sympathy for their plight by using religious mottos that called for the respecting of their historical rights – but that were also consistent with the basic tenets of the revolution. At the same time, a feast celebrating the construction of the world's tallest concrete dam was being held in Iran by the then-president; the situation was tense enough for talks to be held on the water dispute while the farmers' sit-in continued. As a result of these negotiations, each of the farmers received compensation of €1,100 a year for drought damage, and the rural district of Dehestan also became a larger jurisdiction (Shahrestan). They also promised and received a moratorium for drought loans. This kind of entitlement to water rights was unprecedented in modern Iran, as the highest offices in the country were obliged to use the carrot rather than the stick in dealing with well-informed and disgruntled citizens. Eventually water was released into the river from the dam, but only for a few months. And sadly, the trans-basin water conveyance pipeline was smashed by irate drought-stricken farmers. However, they had already agreed to be paid in exchange for allowing the pipeline ditch to cross over their farmlands.

There are different sorts of terms in multi-actor system contexts with different definitions to label the parties' roles in a system. For example, stakeholders are people or groups who hold the power to affect the straightforward (future of a) system (Jones and Wicks, 1999) and the loss of that implies powerless stakeholders. However for now we will present actors as a group of people – a beneficial or relevant party, regardless of having palpable power[40].

To discuss the implications of the method in the next section we will use an actor- analysis. Again we stress that the analysis is primarily used here to explore the links between the actors. Using that we will have a basic understanding of the problem and networks, because it is often unclear 'which actors need to be involved in [and/or responsible for] a water management effort' (Islam and Susskind, 2013: 93). The dense and complex nature of the *Zayandehrud* conflict, as an issue played out by many 'hands' (Figure 18), meant it was difficult at times to access the central actors. We believe the readability of the chapter could be improved if the number of the actors that are involved in the analysis section is reduced. Backed by this, we are inevitably focusing on two of the actors, as we think in such complicated cases the fewest actors can explain this water business clearer. In the conclusion we interpret about those actors that can arguably benefit the conflict resolution. Here we rest our case. Henceforth we will slightly move into our main discussion, the actors: those

[40] An actor differs from a stakeholder in this respect. For the definitions refer to the footnote in page 37.

who are playing (in)directly with this water beside the norms in which they are conflicting over or looking for.

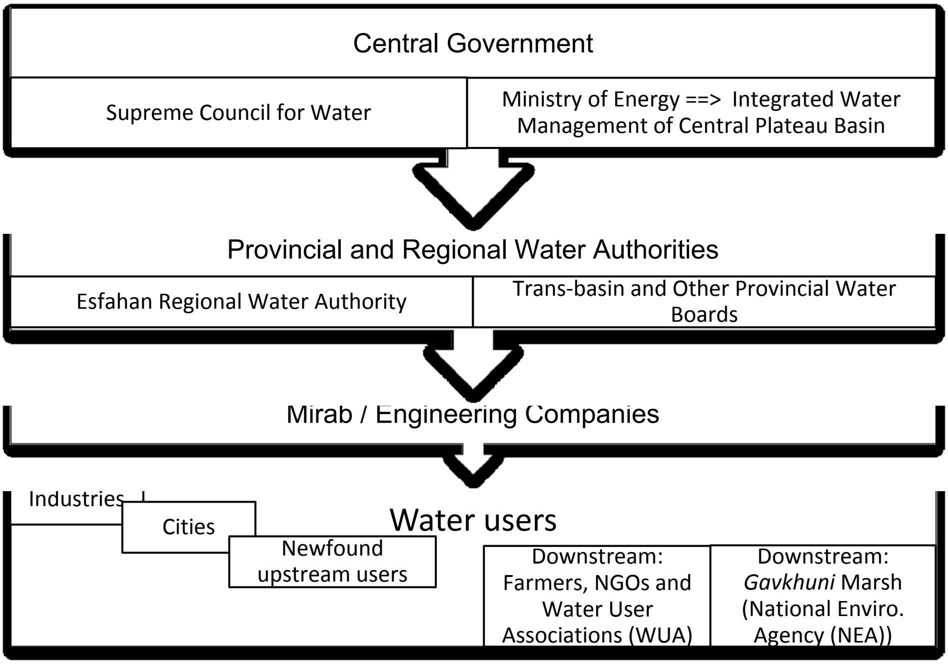

Figure 18: Hierarchical system of the *Zayandehrud* showing the actors

4.3. The actors involved in Zayandehrud

4.3.1. The government (water authorities and governors)

As the main river course, main actors and a large part of the river basin are located in Isfahan Province and most of the river's water comes from Chaharmahal-va-Bakhtiari Province, this has led to some jurisdictional misunderstandings and a lack of agreement over historical rights is far from being resolved. There are reports that upstream users are knowingly using more than their allotment, if any exists (Eslami 2010). Moreover, periodic and country-wide droughts escalate dramatically in sub-national conflicts, as well as *Zayandehrud*. The severity of such socio-ecological conditions has influenced the decisions to make some so-called 'stepwise, decisive and practical' decisions translated into Integrated Water Resources Management; however the downstream users (mostly farmers) have been realizing that it has disgraced their 500-year water-rights. For example, the Ministry of Energy has frequently curtailed the downstream users' water by declining the released discharge from the *Chadegan* reservoir as the upstream users (in Chaharmahal-va-Bakhtiari Province) are constantly pumping and using water for (highland) orchards and remote cities. It is not long since these uppermost lands were vested (directly by the former populist President) and vague and non-peer-reviewed land-water licenses were created. That by itself is still causing chaos in the river rights and is also one of the reasons why others have violated these water rights. These licences override the pre-existing rights that are hundreds of years old of a huge population[41] in the downstream from a water coming from hundreds of kilometres away. This issue of overriding the rights is not confined to the former presidents; the President presently in office has promised the uphill province to build a tunnel that has been proposed by engineers and a dam (though the volume is low) which has caused an extra load on the river to afford drinking water for another remote city.

Remarkably the large industries in Esfahan and Yazd Province have also been grappling with this provincial conflict. As for Chaharmahal-va-Bakhtiari Province, many of the employees in these industries have migrated from there and are now Esfahan city dwellers, which is creating extra demands for everything as well as

[41]Esfahan, as the oldest user of the river, has documented its water for the last 500 years (Hossaini 2006; Harandi et al. 2015).

water. Yazd Province is another trans-basin user; its neighbours see it as a user that is carelessly wasting the water with industrial uses.

Such interlocking and networked actors and perceptions have been the causes of tumults between these provinces. By focusing exclusively on dividing the water flow, the government and its related actors are engaged in blame games or spin and not yet in a sincere effort to come to an agreement. Such policies have not taken into account how all of the actors are likely to be affected. Cooperation seems less expected in the actors, however, and there is a real confusion because the governance patterns do not create a community of interest over the actors' communalities and has left actors with numerous concerns and unresolved issues. As shown in Figure 1, the policy making is tightly ruled, made and implemented by a top-down administrative process. At the top are the Ministry of Energy and the representatives are at the provincial levels, some of whose responsibilities have been taken over by the Supreme Council for Water.

The question about all of these (governmental) actors could be: why have disputes grown and the pace of progress has slowed by the gridlock created by the deluge of (inter)provincial and national policies? We shall argue, as our account here shows, that it is because the actors and over-centralized policies are mostly obsessive to the tribal- and geographical-oriented interests rather than responsive to the norms and responsibilities for sharing the river.

4.3.2. The industries

Back to the early 1930s, the idea of having a city like Manchester in Iran turned Esfahan into the home city of the country's textile factories (Atabaki, 2013). It is not so long ago that industries around the *Zayandehrud* were developing based on two different ideologies of development. The first one was rooted in the coordination of provincial agencies at the river-basin level for planning and management (Molle, 2009). This idea in Iran came in and placed agriculture as the backbone of industries' development in the 1950s (after Balali 2011) that is on-going, accordingly. The second ideology was related to the 1980s that placed industries as much as possible in the centre of Iran due to safety and (food) security concerns. The grouping of these two over the years turned Esfahan into Iran's industrial hub. Surely, the *Zayandehrud* river water played a significant role amongst this centrality. The industries are mostly 'linked to government subsidies for livelihoods' (Harandi et al., 2015). Therefore water deliveries have turned out in a way to be managed not just for industries but also for the purposes that would help those industries. The refineries here produce and supply one quarter of the country's petrol demands, however the petrochemical industry has turned parts of its production into oil to elude the sanctions and consequently the water supply must not be cut. These are the examples leading to additional (re)use of the river and the waters that is not 'theirs'. The rights-holders are complaining that these industries can get water illegally.

4.3.3. The Mirab (Company)

Conventionally, governing surface and ground water in the semi-arid areas such as Iran had intrinsic values (Mahmoudian 1969) as it was a societal-based activity and the management of them was performed through an intricate system, known as the *Mirab*. Therefore we can describe a *Mirab* as the head of, for example, a river and a person who apportions water share to the water-right holders. The management of rivers was in the hands of a trustworthy *Mirab* elected by upright local communities' representatives. Only one of these representatives was appointed by the governor. 'Historically the states and central governments rarely directly influenced river management' (Harandi et al. 2015 from Hossaini 2006). He was wisely selected from the hamlets' communities along the central part of the river, to see the river from a normal viewpoint, not from the high-water perspective of the upstream users or the low-water perspective of the downstream people. The *Mirab* of *Zayandehrud* appointed 6 assistants and quite a few observers who were employed as needed. The wages, services of the channels and sharing facilities were entirely paid for by stakeholders based 'upon one's sharing of water' (Mahmoudian 1969; Hossaini 2006; Eslami 2010; Harandi et al. 2015). To devise the governance patterns in the river, the management system was largely local resource- and knowledge-dependent and was implemented according to precise technical- and societal-tuned mechanisms. Perry (2013) describes the distribution process of *Mirab*s as follows: 'The infrastructure in all these systems provides the capacity to deliver the service that the other elements – how much water is available, priorities for sharing, rules and management arrangements – combine to define. As well as the channel or diversion structures that deliver the water, the infrastructure may also include water-dividing structures, reflecting different shares. Nearly identical structures are found in Nepal, dividing hill streams to serve farmer groups.' An eloquent socio-technical rationality for the *Zayandehrud* water apportionment came in the compilation of a guidebook (a *Tumar)* that was the work of *Sheikh-Bahai*, a sixteenth-century Iranian polymath, to allot the river water into 33 portions for 6 districts (Fig. 19) (Harandi et al., 2015). This auto-regulating socio-spatial mechanism embraced the whole range of users as well as e-flow of the *Gavkhuni* swampland (which is registered by the Ramsar Convention), where the river terminates (Beaumont 1974). The *Tumar* included each hamlet's share of the river in terms of volume and time, allocating the available natural inflow, which influenced the extent of the cultivation accordingly.

I recall that the cities and industries gained a priority. This has gradually thwarted the rights and the lasting water distribution algorithms of the *Tumar*. The 'fuzzy allocation' scenarios of the earlier orders and 'its attendant social organization and local knowledge' (Molle and Mamanpoush 2012) were thus overridden and replaced by a new but unreliable and amorphous governance pattern.

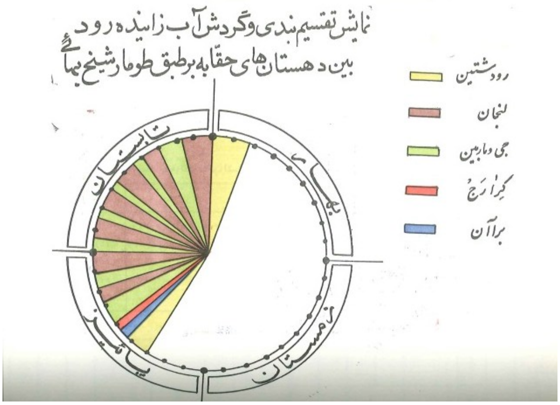

Figure 19: Water cycle in the past in the *Zayandehrud* (Mahmoudian, 1969). The pie chart represents the Districts' water circulation in one year in four separate seasons. Each slice is the period that users of the district can use the river's water according to the *Tumar guidebook*. The five colours are for six districts (green is for the two of the districts). The period of extraction of water in the river, mandated by the *Tumar*, was restricted to just 168 days a year (6th June-21st Nov), and the rest was open to use.

Perry (2013) has called attention to water resources privatization that has delegated the 'state functions to private and non-sate actors'. He has also pointed out the problem of 're-scaling of state responsibilities' by shifting authorities toward up- and downward sectors and/or levels (e.g. from international, to provincial, to enterprise levels). The idea that favours private rather than state operators (not

NGOs) has allowed former staff from ERWA to found 'their own companies and to perform the same service, albeit at a higher cost and private benefit to themselves, and with no increase in accountability[42]' (Molle and Mamanpoush, 2012; said also tacitly by Harandi et al., 2015). Accordingly, the *Mirab* Company was founded in 1993 and the government fully changed the old *Mirab* system into a state-based agency involved in operation, maintenance and remedial measures. Hossaini (2006) has criticised the management in the *Zayandehrud* and holds as a 'chronic illness', as well as the Mirab Company.

4.3.4. Engineers

In Subsection 5.2.1 we touched on the linkage of engineers with government and technology. It goes without saying that engineering projects often come up with new ideas typically because of a desire identified by their customers. Like many other river basins, in the Zayandehrud the basin development has been fostered by utilitarian engineers (Harandi and De Vries, 2014) to serve — most probably subconsciously, three criteria of development engineering artefacts: needs, requirements and specifications' for 'testing, evaluation and readjustment of different design solutions' (Björnberg, 2013). With few exceptions, engineers as companies (consultants and contractors) and as advisors are forceful drivers of any planned development as they see a river basin as an artefact that could be shaped by 'engineering'. There are countless signposts to show that the engineers' values have seduced the other values to play out their roles. The companies in the fields of water

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[42] Swyngedouw et al. (2002) have criticised some neoliberals' views on this value. They hold: 'Indeed, accountability channels are often gray, non-formalized, and nontransparent, frequently circumventing traditional democratic channels of accountability. […] Finally - and most importantly - participation is rarely statutory, but operates through co-optation and invitation, usually by the key power brokers within institutions'.

have gradually and unconsciously fuelled the disputes by proposing such proposals. Molle and Mamanpoush (2012) have aptly described another case as a series of cascade projects to argue about; the generation of a critical situation of unpredictable, invisible and ignored actors that has been created by the manipulation of the hydrologic cycle of the *Zayandehrud*:

‘To increase the value and usefulness of the *Khamiran* dam [a dam located in the lateral valleys of the Zayandehrud] and extend the benefits of the *Chadegan* reservoir to other valleys, a plan was drawn to pump water from the latter over the mountain ridge into the former […]. In 1991, the *Karvan* pump station was constructed for that purpose but *it faced severe technical problems* [authors’ italics] and its operation was discontinued after 3 or 4 years.’

The International Federation of Consulting Engineers (FIDIC) recognises the work of the consulting engineering as ‘critical to the achievement of sustainable development of society and the environment’ (FIDIC, 2014). Explicitly, engineering obligation is crushed if others interfere with such obligations and the abovementioned three components are compromised. Yet although gigantism (Harandi et al., 2015) fervour has waned, drought itself remains a source of legitimacy for projecting the river. The account showed that we can liberate ourselves from the notion of ‘just drought caused this chaos’ when looking at what is being proposed by engineers to manufacture more water. However, Zhang (2012) holds that ‘although technical experts were invited to contribute to the decision-making, they only played the role of “experts offering suggestions”. Government officials made the final decision and the influence of engineers remained relatively weak’.

4.3.5. The farmers

The last key actor we wish to touch upon in this section deserves more space because as the main and the oldest share/right holders, the river was and is the mainstay of the farmers. As the downstream farmers (D-farmers) own more than half of the shares of the river, according to the edict, and the fact that in recent years, we have too often seen a ceaseless sequence of issues between D-farmers and Esfahan Regional Water Authority (ERWA), therefore we wish to focus on them in this subsection. Since 2000, the river has faced continual and drastic water shortages although the D-farmers were not informed adequately in advance. As the dry conditions have continued officials have kept on supplying more water to the industries, cities and released the remainder to the farmers – recently biannually, and often grudgingly. This is because generally there is a sense that agriculture is drinking up the river and the abnormally dry conditions are exacerbating this. Despite numerous attempts to restore water due to a lack of water, the D-farmers are unemployed, their trees have died and been used as firewood, their livestock and equipment have been sold and acres of their lands have been left uncultivated. Scholarly articles aside, dozens of domestic and international news stories about the Zayandehrud situation have continued to come out. There are lots of news stories about this conflict in the media streams and perhaps the best way to present the deterioration in the condition of this patient is by quoting them: 'Farmers who worked the fertile lands around Isfahan have had to find a new way to make a living since the river at the heart of this Iranian city ran dry. Instead of raising and selling crops irrigated by the Zayandeh Roud, they are now paid to keep its parched riverbed clean and litter-free' (Bozorgmehr, 2014). The farmers in [Iran's] central Isfahan province have for years complained against unfair apportionment and diversion of their shares of the Zayandehrud River to supply others. It is leaving their farms dry and threatening their livelihoods. These downstream water shareholders of the Zayandehrud River struck out toward the government building, but this time riding on their otherwise redundant tractors.

On the other hand, although other water seekers of the Zayandehrud River have been presented with opportunities by their bargaining power (Molle and Mamanpoush, 2012), the D-farmers have realized their shares are gradually being reduced. They had (have) their convincing argumentations:

Firstly, Isfahan City, in the middle reaches of the river, owing to technology, industrialization and greed for growing, has become a metropolitan of millions of citizens. Nearly half of the *Chadegan* Reservoir capacity is taken by the city and other small nearby cities and hamlets, as they are the non-removable consumers of the river's water these days although they did not yet exist in the recent past.

The second reason is rooted in the new-found upstream users' abstractions vested by the then president (recall Subsection 5.3). In Chaharmahal-va-Bakhtiari Province, recent on-site and heterogenic (*ad hoc*) decisions taken by government allies have caused the development of orchards upon the hills of the *Chadegan* Reservoir and have complicated the conflict between the up and downstream parts of the river. In this occasion, the D-farmers requested their right-of-river by writing letters to the officials and holding sit-ins. Yet, they welcomed credible commitment from any party to deal with the overlooked rights from the river. Whilst U-users have been trying to use political circles, others think that it is a superficial reason for abstracting water.

Thirdly, the trans-basin projects, where the projects have been biased toward politicians[43]. The water that must be allocated solely for drinking is now also being tapped by (unknown) industries in the Yazd province.

The same situation is happening in the whole dispute of the *Zayandehrud* as some deals were actually set out in reasonable terms, such as *Beheshtabad*'s trans-basin project where Isfahan, Yazd and Kerman own the plan and Chaharmahal-va-Bakhtiari and Khuzestan provinces do not cooperate there. The project has faced unforeseen political challenges at the national and local level rather than technical issues. The previous client (ERWA) has been recently changed due to such conflicts and it has now been replaced by one of the wealthiest governmental companies – the Iran Water and Power Company. However some industries have allegedly bought this water in advance. Such a good wholesale deal has reassured the downstream rights-holders (farmers) of the basin that will receive no reliable water instead of the rights. The situation was very similar to what Hu et al. (2014) depicted about a Chinese case; 'the market-based instruments widely adopted by the government to achieve an efficient allocation of water resources in arid regions have not provided sufficient incentives for farmers to improve irrigation management.' However there is some talk by farmers and others about legal action against the ERWA and its contractor-led companies and there are persistent anti-trust rumours that may cause society some real 'headaches'.

Nothing nowadays could be diverted from the river as it has fully dried up — from downstream of the node where the river is flooding the industries. The

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[43] 'I.e. demand of water by the cities of Yazd and Rafsanjan, which lie out of the basin but are home to former Presidents' (Molle and Mamanpoush, 2012)

groundwater is also in the process of drying up. As mentioned before, the water rights have dwindled and as a result their incomes, social side effect of the policies (growing number of conflicts) have appeared: after leaving their hamlets years ago, underemployed farmers found themselves in a series of low-paying, often back-breaking jobs. An example of such jobs is the loading of trucks to take fertilizer for some of out-of-the-basin destinations that have already been allotted the river water. Those who could (particularly the youth) have fled to the neighbouring cities to find a (decent) job.

To change, they found themselves sitting on the tractors covered with banners proclaiming 'neglected rights ought to be mooted', 'traditional water rights come from our ancestors' heritage', and 'do revive the *Zayandehrud*'. The farmers tried to draw sympathy by having religious sayings respecting their rights albeit consistent with the basics of the religion of Islam and the revolution. Concurrently, the opening ceremony for the construction of the world's tallest concrete dam was taking place as an engineering feat. Sad scenes were seen, where the trans-basin water conveyance pipeline of Yazd city was smashed by irate drought-stricken people. The water scarcity was acute enough to hold talks with officials even though the farmers' sit-ins continued. The farmers had agreed with the government that they would receive compensation for drought damage (subject to the Law for Fair Distribution of Water). The governor made many other promises such as a moratorium on the repayment of the loans. All this was not to say that we embrace the whole range of the farmers' actions, because they had already agreed to be paid to allow the pipeline ditch to cross over their farmlands.

4.3.6. The other actors

Molle and Mamanpoush (2012) analyse the *Zayandehrud* case study to show how fiat measures have led actors into controversies and 'not surprisingly, those most commonly affected […] the downstream users, the next generations and the environment, in decreasing order of bargaining power'. Quite often, the environment is the only voice in the decision-makers' room that is not 'right' and does not have rights. The policies have not left any room for manoeuvring in extreme events and the environment is the first victim of such water curtailment scenarios. The environment is not an actor solely because it does not have intentions. But of course it is an important user that has its own responsibilities/actor, (Iran's) Department(s) of the Environment (IDE). Therefore, the IDE has umbrella norms, to deserve and care for the environment. The importance of the environment totally and entirely depends on who takes care of it, because it is this actor, the IDE; who decides what is the relevance of the environment? Some actors hold this norm and some actors do not. Like the economy, some actors hold money high as a value while some others may say they do not care about it because they do not depend on it economically. The IDE plays a passive role in the governmental sectors as do the Chamber of Commerce, the City Council and some farmers' NGOs, and they are also less influential actors in the non-governmental sectors too.

Amongst the overlooked actors in this controversial situation who are not only the farmers and the environment, we also see the next generation. The next generation, which is another loser, is trying to sort out its values linked to those actors who are putting them at the top of priorities. The point is that both the next generation as well as the other actors such as the NGOs have their own values and they can choose not to cooperate and can frustrate the procedures of development.

4.4. The actor analysis of the Zayandehrud; an invisible hand versus many hands

This might be a repeated introduction for this chapter but we are looking at water as a resource that has interchangeable and straight parameters influenced by climate change and therefore as an example of a situation in which the problem of many hands seems to occur (Van de Poel et al. 2012). Van de Poel et al. (2012:55) attribute capacity, causality, knowledge, freedom and wrong-doing as five conditions that actors and norms intersect. The problem of many hands may lead us to narrow down the number of the actors for the analysis.

Figure 20 elucidates how the actors are related; in fact in the analysis of the actors is a set of black boxes. They do not look into what they are doing and remain closed. But in order to realize answers to the questions: What are these actors really capable of? What are they entitled to do, forbidden to do and what powers do they have, we will present a secondary analysis to open up the boxes and then inside we will see the 'practices'. However, it eventually is very much dependent on what the chapter's messages are. If our message was to show the relevance of actor(s), network(s) and issue(s) then we needed a complete and figurative picture of all the actors because it is necessary to show which power is trying to pull or push (other) actors into different directions. Against this, if we want to show something theoretically about friction points between actors — a theoretical model that explains what the problem is that has caused conflict and what is central to the cause of the problems — then, a carefully handpicked number of actors and another analysis is preferred.

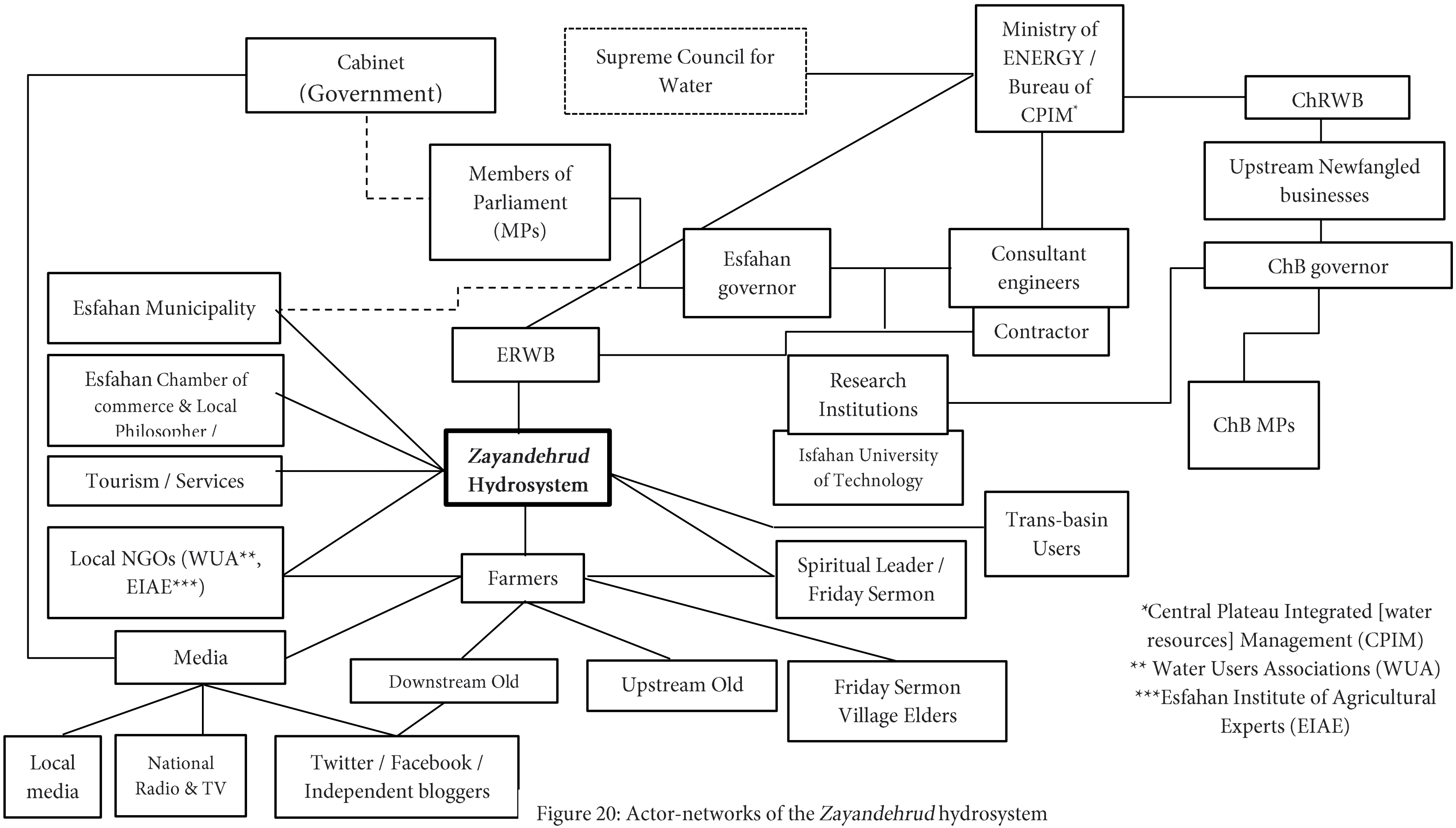

Figure 20: Actor-networks of the *Zayandehrud* hydrosystem

4.5. Actor as a 'practice'

We need to teach the actor-water-user how to (inter)act within the boundaries, the actor-engineer and the actor-decision-maker 'how to play observe and study the game critically and [...] how to devise the whole game properly' (Floridi 2014:85). What it is missing here is defining a model/theory/idea to work to achieve this purpose as a 'magic sword' and clears the action's boundaries and the constitutive functions of actors, which is the Normative Practice idea (henceforth NP). The idea of NP is simple, but can be misleading when we define a concept of 'practice'. We want to use individual people or organisations or an organized group (like the farmers made) but in practice we have found only actors and they are human beings who have a will, interests and intentions.

This section is loosely based on the previous chapter. It has sketched this idea with a comparison of a water manager as an actor in two historic positions, and have shown the (friction) points that can internally change the value(s) *within* actors. The new point of this chapter is to show that conflict *between* the actors in fact 'is a clash of interests'.

By asking who is now holding responsibility in such interlocking-by-technology systems we will return to water-related practices in the next section.

4.6. Secondary analysis

The development of large hydraulic units and the liability of having the whole responsibility of water resources for a group of actors could be 'a fix that can backfire' (Gohari et al., 2013). Any technological development is something in which all actors are interrelated so there is always a chance of tensions between the different practices. We see that development plans in the *Zayandehrud* have endlessly changed the norms of the actors; therefore in a way we are talking about a technologically networked river in which the practices have to take or implement decisions on the same phenomena with different norms. However it is not a technology that directly connects them although we claim that in a way, of course, they are norms accompanied by the technology. That is how in this case technology (recall the dam and trans-basin water conveyance projects) creates a connection between practices.

The government reasoning for certain norms tries to push them onto another actor and this has probably led to an impasse. And in fact, then tension arises between the *structural norms* of the actors when these new values are being pushed by another actor. The same thing happens here because the government pushes certain values upon the farmers in the *Zayandehrud*. That is why the farmers resist. Especially when one tries to influence the other then that can cause tensions internally and that is only the result of trying to force an unnatural practice. For example, for many years the government and engineers have been encouraging farmers to change their cropping patterns and to flood their crops to make them consistent with the national market values or/and import-export policies. It is not the others' responsibility because for instance the government's responsibility is to foster justice, in order to enrich laws. As the government has thoroughly different accountabilities, the whole issue has become mixed and that is why tensions can arise.

The reluctance of farmers to agree with government values may not be the cause of the current conflicts, but only an expression of the inappropriateness of the values that are being pushed because theirs are truly different from other actors. Such changes could be performed in association with some NGOs, if we assume they can engage in. The government, *Mirab* or engineers might not have the (indigenous) knowledge nor the responsibility that a farmer does. They are trying to force themselves into the farmer's normative practice. The farmer himself is also overruled in this area even though he has responsibility to conserve water through participatory processes, but the government has overridden the farmers' responsibility in this part as well.

The research has reiterated that structural norms are things that are organized and not to be interfered with by others. In the government there are departments, all of which have tasks and responsibilities that are structural. However they have certain higher-ordered values such as sustainability or holding power etc., which is what we call *directional norms*. The problem is not only in the higher-order value level (refer to *directional norms* such as autonomy, welfare, transparency, frugality etc.) but it can also cause a conflict with tasks and responsibilities in the lower level.

What are the main differences between the government and the farmers in terms of value and interests? From the normative practice idea we understand that if they all work with a proper *structure* and they fit in the *direction* - they work together in a normal situation, then everything should be alright. A conflict does not necessarily emerge when different actors have different directions, because it is essential to move forward in each society. The problem emerges when there are tensions between different actors that somehow should have the same direction or the same structure for certain purposes, and then it does not work anymore. As long as decision-makers keep practices as they are then there will always be conflict. This is because there is inherently conflict and something in either one or both practices has to change to make them fit well together. The government is there to protect justice and the environment, and farmers have more economic and to some extent environmental interests. If one makes changes there that do not fit with the direction then something really has to go wrong. If the government decides not to go for justice and instead goes for making money[44], for instance that is a very important shift, of course because they are taking a totally different responsibility. If there had been a set of contextual rules then the change might have been less dramatic. It was routine to find consultant engineering companies to design projects linked directly to the Energy Ministry which itself is mixing engineering and government practices in the case of structural and directional norms, particularly where designing the major projects was fully in the hands of such public-private companies.

In the face of all this, the conflicts are also in structures when for example the government has a target for taking over the responsibilities of the farmers. It is immature when other actors give the government credit for a new (structural) value because it is not what they should do. For the government we would expect justice to be an important value. If they started taking the economy for example as the most important value something hilarious would happen because of the change in direction. It can also go wrong on the farmers' side. Their primary concern should be to survive economically, we suppose. The generous subsidies have encouraged farmers to overflow the yields with water without a thought to their value or to conservation (Nair 2014). A rotation of norms, the farmers had a tacit tendency to take compensation - however although that was legal, to allow the government to cross their land for new projects, in fact it was another push-pull dichotomy in this conflict. Nonetheless, they primarily bowed on the trans-basin conveyance projects

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[44] It's okay if we like money, as long as we remember to love people more. – Simon Sinek

- by getting money, but such changes in the values have led them to rework their practices.

4.7. Conclusion: redefining the higher level and jeopardizing lower level norms

There is no easy answer to the question of how best to balance all the competing water uses priorities of the conflicts. However, analysing water conflicts in terms of conflicting values generates insights that other analyses cannot offer. The *Zayandehrud* case showed how an intense tussle over the water can be shaped due to redefining the higher level and jeopardizing lower level norms (tasks and responsibilities). Over the last several decades, utilitarian gigantism (Heidegger 1954) in the *Zayandehrud* hydrosystem has produced such mega-actors (giant cities, industries and extended farmlands) that traditional systems would no longer meet all their needs. The agents and both public and private sectors have gradually undertaken the responsibility for water, and their ambitions have been replaced with others' norms. This part of the research sorts through the argumentation that conflicts around the water resources development can be not only the matter of higher other-values but it can also be the case that parties reasoning for certain values try to push these values on another actor. However, a conflict can arise with tasks and responsibilities at the lower level.

To a large extent, the *Zayandehrud* case fruitfully represents the trends of the practices and conflicts - within socio-technical systems - that have been drawn by the technologies proportionally to the projects aimed to call more water for/from distant regions. *The sin of this strategy is that in general it cannot predict (if it does not overlook or ignore) the role of society and nature, in fact the norms.*

We have demonstrated the theory of normative practice to contribute to what Berkes (2002 and 2010) acknowledges about ‘cross-scale institutional linkage’, ‘effects of higher level institutions on local institutions’ and devolution of resources governance which nowadays is strictly needed to reappraise in every conflict resolution mechanism, as well as within hydrosystems. Normative practice analysis could be practiced as a part of the decision-making process rules. The NP analysis showed that if one starts interfering in the other(s), new tensions will arise because of a mixture of different structures, although conceivably all the responsibilities could remain the same. Especially when directions and structures get mixed between actors, e.g. when the government starts doing things that actor-farmers should have a say about, real tension can arise. ‘This emphasis fit[s] broadly with a role for governments as ‘setting the rules’ rather than actively managing decisions, and it [is] aligned with the shift in emphasis from ‘government to governance’ in environmental discourse’ (Schmidt, 2014 from Head 2004).

Drawing on Minoia (2012), the current ‘water institutional abandonment’ has become contradictory to the current setting of the hydrosystems’ governance. His reasoning is laid with this argumentation: ‘water-saving and demand management [which] are embraced by policy-makers as solutions to the current crisis are misplaced if current water management policies ‘do not consider the agricultural, environmental and social restructuring that have reshaped the area’. We need differently-minded decision-makers to realize that the ‘*problems cannot be solved within the mindset that created them*’ (Brelet 2004).

In that sense, (good) governance cannot be created by command-and-control rules, only influenced - governance just ‘is’ (Wegerich et al. 2014). Nevertheless, ’if one sector is favoured, then this is a failure to deliver an ethical policy’ (Brelet

2004). The water supply industry should consider to whom it is accountable and whether its data is accessible and how it allows stakeholders to participate in its management decisions.

What it has done in this portion of the thesis - which in fact is new to previous considerations not only in this case of water management but in STS studies, is that a combination of actor network studies and normative practice has been used and that seems to be a fruitful and strong collaboration. The actor analysis is an invaluable ally for NP because it allowed us to select and cherry-pick the highly influential actors, while otherwise in the NP analysis we have to deal with too many of them. We suggest that a combination is used in other fields, as well. This chapter has also contributed to the work already shown in the books by de Vries et al., (2012) and Christensen et al. (2012). They have shown most specifically that the roles of norms and values are very important.

We have also addressed the actor-engineer as an example to show how they fuel conflicts. Geels (2004) has blamed such lopsided views that can make engineers 'blind to developments outside their focus[es]'. These contemporary engineering practices produce technological, ecological, and social risks (Christensen et al., 2012). There are no easy solutions to this dilemma, but it seems engineers, hydrologists and socio-technical analysts are largely at fault because due to greed the engineering companies are failing to properly plan the most effective use of all the water resources in an area, country or region where water must be shared. Indeed the actor-the-engineer needs to deal with water through its value. In fact engineering normative practice must be consistent with societal and environmental norms to seek a balance between ethical responsibility and pluralism, to coordinate tasks and plans (Christensen et al., 2012). As negotiating, trading off different competing requirements, customer needs and design specifications are central 'in the engineering design process, there is a need to investigate what normative criteria the goals should meet to be successful: What is a good (i.e. functional or rational) engineering goal' (Björnberg 2013)? This process enables us to rapidly identify and address the inconsistencies. One would hope that such views expressed in this chapter would lead to improvement. However, that is not going to happen in the near future, where 'the challenge is to reconcile our roles as agents within nature and as stewards of nature' (Floridi 2014).

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CHAPTER 6

Conclusion and Recommendations

6.1. A short introduction to the outcomes

This thesis provided a new insight into the possibilities and limitations of technical, managerial and negotiated approaches to water governance, normative approach. It argued for a normative approach in this field. The key questions asked were whether the normative practice framework reveals the failures of water governance regimes in the Zayandehrud case, and if so how this analysis can contribute to improved water governance both in this case and more generally. This overarching question about the Zayandehrud was linked to four sub-questions.

Sub-Question 1 focused on the inability of current DSSs to preserve the river. Sub-Question 2 asked whether the failure of the water governance in this case can be understood as a failure to connect with the past. Sub-Question 3 proposed to understand water management as a normative practice. Finally, Sub-Question 4 investigated how such a normative practice framework could be combined with actors or stakeholder analysis, in order to reveal the dependencies of actor-networks. The thesis addressed these questions from historical, empirical and ethical perspectives. A concise summary of the outcomes of the thesis is as follows:

Table 7: A summary of the outcomes of the thesis

Outcome	Related Chapter(s)
reframing and reconceptualizing water governance modes	3 and 4
keeping issues of interlocking governances in mind; identifying bottlenecks in actions and perceptions, not in information	4 and 5
viewing water conflict as a social policy problem that needs network analysis rather than system engineering analysis	1, 2 and 5

This thesis analysed the present situation and predicted the future situation of one of Iran's most complex hydrosystems, the Zayandehrud. It is complex because its interventions in social and political systems are not easily controlled. As long as they remain so multifaceted, one cannot expect to find a straightforward solution. Amongst diverse issues, my research examined various institutional and societal aspects of water conflicts (including interventions, collaborations, and the concept of water rights); it also touched on technical aspects of the interventions. It showed what the current approaches are, why the conflict cannot be resolved, and what the possible causes of conflict are. Four reasons were given for water conflicts in the case of the Zayandehrud:

- the lack of applicable real-time decision support systems – more specifically, too much reliance on system engineering rather than network analysis
- the disconnection from history, and the concomitant failure to learn from past engineering skills and practices
- the existence of conflicting norms within the minds of individual actors
- the existence of conflicting norms and interests among the various actors

Theories drawn from ethics and philosophy of technology contributed to a civil engineering offshoot: water management. In this thesis, this was achieved by applying the normative practice framework to the Zayandehrud case. The framework provided a basic vocabulary for exploring the presence or absence of certain attributes in the Zayandehrud governance. It allowed me to explain why the absence of those criteria can cause conflict. As a governance instrument, the proposed framework would create policies to help resolve such situations.

In this thesis, 'practice' was described as 'a well-defined activity that *should* achieve a goal.' The activity could be engineering or membership in a club, and the goal could be welfare, food security, or making a good investment. This portion of the work averred that, crucially, *water-management practice* is a *normative practice (*recall Section 4.5.); of course, this means that it is governed by certain rules.

Earlier research has already applied the normative practice framework to domains such as healthcare and the military. Water management is a new application, however, and my analysis thus represents a major contribution to the field. In this way, the thesis confirmed the value of this philosophical tool; it generated genuinely original insights, quite different from those associated with the healthcare and military domains. It did so by applying two analyses simultaneously: actor analysis and normative practice theory. The former elucidated how the actors are interconnected. The latter revealed the actors' capabilities. My use of actor or stakeholder analysis aligned with my introductory discussions of the replacement of system thinking with network thinking. Chapter 5 presented a secondary analysis of hitherto-concealed normative practices. Recall Chapter 4, which showed that if there is a conflict in a hydrosystem, it may relate to the internal interests, tasks and norms of a practice rather than solely to ideas about water. If we change one direction (value), then tensions may arise *within the practices*. This is not new that the controlling water by command-and-control policies is not going to work anymore, but another key insight that the thesis offered, therefore is: the world needs to monitor the ever-changing values in order to deal with difficult (water) governance problems. .

I also considered the ways in which values play out *among* practices. I showed that norms can create conflicts *within systems*. Chapter 5 demonstrated that *the different norms of different actors* can cause clashes of interests and values.

All in all, the thesis argued that the water management paradigms that are currently used to resolve such dilemmas are no longer sufficient. Water managers, policymakers and engineers must realize that they need the rest of the planet to move from forecasting models to 'fore-sighting' frameworks. Forecasting models allow us to understand the problems scientifically. However, this is not all there is to say about water problems. Rescher (2013), for example, argues that modeling has nothing to do with *how* the system works. The theories I proposed in this thesis explain not only how systems and networks function but also how certain rules apply in this context (Rescher, 2013).

6.2. Answering the research questions

How did my sub-questions shed light on the central research question? The normative practice framework illuminated institutional gaps among different types of practices (as in the Zayandehrud conflict), such as water-manager-as-practitioner and engineer-as-practitioner. Ultimately, I concluded that normative practice is a suitable framework for conflict resolution processes. I showed how complex and interconnected the relations among actors are, and how intractable their values are. I argued all of them based on four pillars: the notion of the qualifying role[45], the normative practice framework, actor or stakeholder analysis, and the considerations of the problems related to conflicting interests among the water network components.

[45] I explain this notion in Sub-question 2.

Sub-question 1: Why can't current decision support systems fully prevent the Zayandehrud from experiencing a socio-ecological breakdown, and what new method(s) can be proposed as a redefined DSS for analysing the river's long-term behaviour?

Chapter 2 showed that, even technically speaking, there are still some pitfalls and uncharted territories associated with the complex nature of decision-making processes in the Zayandehrud. How might current decision support tools lead to the degradation of natural systems? How might the current periodical releases of water from the Zayandehrud Reservoir affect the river's long-term behaviour? Chapter 2 contained the thesis's first evidence for the river's governance system failure, which is also signalled by the river drying up. Chapter 2 also drew analytical conclusions about the current and future impacts of past decisions. It proposed a genuine analytical model (non-equilibrium systems driven by Dichotomous Markov Noise, DMN), which engineers are fond of, for physically monitoring events in the river. Thus answering the first sub-question of the thesis revealed a) the fact that the river's prolonged dryness is a consequence of the current flow of decision-making processes, and b) the necessity of using a *real-time DSS*. Running the DSS model would pare down the complexities of the river because DMN works to simulate the random behaviours of a natural phenomenon.

What the chapter argued about the river's long-term behaviour deserves more attention. The chapter's conclusion showed that the water level driven by the DMN method falls in the decreasing level (ODL) class. Put simply, according to this method, *the Zayandehrud will probably be dried up forever.* This is another indication for the system failure that was embedded in the main research question with the notion of *failure*.

This verified that the river cannot deal with the legacies of impaired allocation, over-exploitation and, most importantly, inappropriate governance patterns, such as IWRM. Summarizing the conclusion of this chapter and the claims of the introductory chapter, I found no difficulty in identifying the IWRM as an unapproachable axiom when societal, physical and political boundaries conflict. Accordingly, in a recent Water Diplomacy Workshop (2015), Shafiqul Islam has promoted asking broad-ranging questions about the IWRM paradigm:

- Is it a scientific concept,
- is it a complex construction of a program or project,
- is it a discursive framework,
- is it a policy agenda, or
- is it a set of management guidelines, a tool or goal?

Nevertheless, the thesis also looked into other possible causes of the Zayandehrud problem. Another key cause stems from gaps in historical knowledge of engineering practice. Chapter 3 attempted to identify them.

Sub-question 2: Can the failure in the water governance of the Zayandehrud be explained by the modern approach that neglects lessons from the past and ignores the continuity between old and new water engineering systems, seeing water primarily as a resource?

To answer this question, a case study of an urban drainage plan was surveyed. It described an engineering solution modelled on a Qanat that was formerly located alongside the Zayandehrud plain. The chapter, by describing the functions and characteristics of Qanat technology, reiterated that these engineering feats have social values and can bridge modern and traditional perspectives. My reason for focusing on Qanats was that they are technologically simple, architecturally sophisticated, but represent the values of sustainable development. Explaining the modern alternative for solving the problem that engineers had in mind challenged the local water governance regime. Such regimes depend on solutions driven by a modern mind-set; they overlook crucial lessons from the past. The chapter showcased the knowledge, construction skills, plans, and calculations behind Qanats. I aimed to demonstrate that hydraulic heritage systems are both real and valuable, and historically-based thinking is not obsolete (after Wescoat, 2014).

In connection to groundwater, a resource that throws people into conflict these days, the chapter also elucidated how elaborate and empirically reliable Qanats are. This implies that as long as engineering norms are consistent with natural systems' values, the two are closely connected.

The most original element of this chapter was the notion of the *qualifying role*, which allowed the thesis to enter new territory by considering a value-laden approach discussed in Chapter 4. Before summing up the answers to the next sub-question, I shall re-interpret two of the thesis's contributions that are related to both Sub-Question 2 and Sub-Question 3.

The first is about the qualifying role – that is, the role an actor can play given the competencies she has acquired in the past. As mentioned in Chapter 3, by using the notion of the qualifying role, I point out the usefulness of Qanat technology, in a way that the engineer-as-practitioner may wish to employ it in semi-arid areas. The chapter illustrated this notion via a case study that underscored the skills needed to govern, plan and construct Qanats. Thus I addressed the underlying forces of a technological tradition, defined as modern thinking.

At the same time, Chapters 3 and 4 focused on preventing or halting the deterioration of traditional technology. They sought to establish that modern thinking (i.e. capitalist views about water as a rare and profitable good) has generated the gravest-ever conflicts over rights to water in the Zayandehrud.

Sub-question 3: Can the governance of the Zayandehrud be understood as a normative practice? If so, how can the distribution of responsibilities, interests and norms, as analysed by the normative practice framework, be seen as a cause of the conflicts that have arisen in the water governance of this river? How are different ways of thinking in the Zayandehrud case reshaping the distribution of responsibilities, interests and norms that are causing the conflict within a water-management 'practice'?

Chapter 4 began by showing that water management is a normative practice. Then by applying the relevant theory, it demonstrated that this framework elucidates the distribution of the responsibilities of the *Mirab* (the traditional water governance system) as a water-manager and as a practice. However, the *foundational, qualifying, conditioning* and *regulative* rules attributed to the framework revealed what the *Mirab* was and is entitled to do; where, precisely, do its boundaries lie? In Chapter 4, pages 128-132 in Table 6, I described the rules of the *Mirab*'s normative practice. Here skills, final goals, a technical handbook, physical dimensions, economic norms, and the finality of both *Mirab* systems were clearly depicted.

The third part of the question relates water governance to values. I reformulate this issue into several sub-questions. How are the old and new *Mirab*'s interests and norms as a water-management practice shaped and re-shaped? How does one normative practice shift to another normative practice? *A more challenging problem arises when norms create conflicts within systems.* This is how normative practice repeatedly shows its usefulness. Answering the latter question first, this chapter compared modernism to holism, then criticised several mistaken beliefs about water traditions (the tradition of water apportionment, and the notion of *hydraulic mission*). Accordingly, it demonstrated how the old way of thinking has been overtaken by a modern ethos of development. It argued that we need to *return to the old revised system in terms of values and merits*.

The chapter argued that new regimes of water governance *must* 'develop nuanced definitions of "efficiency" and "value" with respect to water that consider economic and ecological dimensions' (Cooper et al., 2015). In doing so, the chapter identified a composite range of values in the virtue ethics context for the old *Mirab*, and found no synonymous indexes in the new *Mirab* practices. The new system has taken state-centred modes, put individuals in the centre (in the form of a CEO for the company) and focused on economic values to augment income as well as efficiency.[46] Such modern capitalist thinking is fundamentally unjust. Therefore, I argued, the new *Mirab* should cease assuming that the company's ultimate goal is to maximize profitability; instead, it is crucial to remain attuned to the needs of a broader cultural-societal system.

In Chapter 4, the thesis again dwelt on Iran's rich history. But this time, rather than focusing on traditional technologies, it looked at the tradition of water management; it argued that the new water-manager-as-practitioner knows very little about this tradition. In the Zayandehrud, policy- and decision-makers need to break down the barriers of rules that govern both negotiated approaches and public participation in water management, in order to make full use of their capabilities

[46] I described the ideology of efficiency in Chapter 4.

and so ease conflicts over water. This is what the old *Mirab* fruitfully did, and science describes this as empowerment. There was an indication of this empowerment when I described the *Mirab*'s services. Users paid entire salary of the old Mirab 'proportionately based upon their share of the river and historically, the states and central governments rarely directly influenced river management' (Chapter 4). Once again, this tradition of water apportionment (as a governance mode in the Zayandehrud) has many advantages, while the modern approach falls short. In fact, the new *Mirab* renews the full support of the agents of the government via yearly manpower contracts.

The chapter discussed localized water governance, an asset holding by a group of local people. This is not a large setup that arbitrarily bestows power on locals; for example, the government still has the right to build a water conveyance system. What I argued about the old *Mirab* governance regime was that it was a kind of leadership practice. As a well-led practice, she did not simply attempt to abstract water resources efficiently. It also relied on people who trusted each other to make the governance modes effective. This view of responsibility is profoundly different from the new *Mirab* system. The old system put a team in place to perform leadership, not to manage; however, representatives of the new governance regime do not talk about such values at all.

Sub-question 4: How do the structural and directional norms of actors in the Zayandehrud development processes clash with one another, and how do they intensify conflicts? Who is responsible for this deadlock?

What should the position of values *among* practices be? How can norms create conflicts within systems? The thesis answered these questions in Chapter 5, pointing to the ways in which clashes among actors' interests, norms and values can cause conflict. In so doing, it built on the previous chapter. The tension that actors experience between restrictions and freedom was conceptualized via the directional and structural rules of the normative practice framework.

For example, for many years the government and engineers' consultancies have been encouraging (if not pushing) farmers to change their agri-business patterns and to make them consistent with market values. As the government uses very different models of accountability and responsibility to enrich laws, values have become mixed – and that is the cause of the problems. At the very beginning of the introduction, I explained this situation. The reluctance of farmers to agree with government values may not be the original cause of the conflict, but rather a reaction to the unfamiliar values that are being imposed upon them. As I said in Chapter 5, 'The government, *Mirab* [Company] or engineers might not have the (indigenous) knowledge nor the responsibility that a farmer does. They are trying to force themselves into the farmer's normative practice. The farmer himself is also overruled in this area even though he has responsibility to conserve water through participatory processes, but the government has overridden the farmers' responsibility in this part as well.'

6.3. Comparison with similar cases

While my research has thus far chiefly focused on the Zayandehrud case study, I will now begin to generalize my findings.

Examples of water conflicts are abundant: they have erupted between Pisa and Florence (1503), between Holland and Spain (1573), in California's Owens Valley (1900-1906), and in drought-ridden Australia (1990s). The Zayandehrud Central Valley bears a particularly strong resemblance to the cases of the Colorado River in the western USA, Lake Urmia in Iran (e.g. Stone, 2015), the Murray-Darling Basin in Australia and the Californian Central Valley[47] (i.e. Lund et al., 2012). Here I will consider California and Australia.

Among many ongoing debates about the California case, I refer to two sources. The first acknowledges the complexity of the case in terms of delaying managerial initiatives.

> 'Repeated management crises suggest that the status quo is unsustainable. Water managers no longer have the flexibility they once had in dealing with the multi-year droughts that are inherent to the California climate. Furthermore, management initiatives are often delayed by the multiplicity of agencies and actors involved and by litigation. Managing the water supply system alone is complicated. But add in the imperative to sustain the ecological and social values of the Delta and every decision becomes unimaginably complex' (Campana, 2015).

The second source is a video created by the Public Policy Institute of California (PPIC, 2015). The similarities between the Zayandehrud case and the situation described in this video are underlined below.

> 'In 2015 California entered into the fourth year of severe <u>drought</u>, a drought made worse by <u>record-high temperatures</u>. Some small communities <u>face severe shortages and need emergency help</u> to supply drinking water. So far major urban areas have weathered the drought without significant economic disruption, but if the drought continues, more communities will be facing tough choices.

[47] Many farmers are receiving no water from irrigation systems for the second year in a row (Circle of Blue). The scarcity pushes farmers further underground (California Water Foundation), and the California groundwater regulation of 2014 has called local agencies to design, then implement and monitor sustainability plans. Many worry that the impacts of these plans will not be seen until after 2040 (Associated Press).

> Agriculture was hit hard. Many farmers were able to switch to groundwater to make up for reduced rainfall and surface water, but farmers still fallowed thousands of acres of cropland. In 2014, this triggered economic losses of two billion dollars and seventeen thousand lost jobs.
> California's natural environment was also hit hard. Low flows in rivers and high water temperatures harm salmon and other fishes. Wildlife refuges struggle to provide enough wetlands for migratory birds. As severe as this drought is, it is not without precedent droughts that are a recurring feature of California's climate.'

Though the state wants to simulate the economically-oriented problem-solving approach implemented for the Murray-Darling Basin of Australia, 'the University of California's [David L.] Feldman said legal and political differences would make it difficult to implement parts of the Australian system in the United States, where water rights remain linked to property rights.'[48] Potential solutions are underlined below, but the complexity of the problems proves that *there is no single silver bullet solution or even set of solutions.* PPIC (2015) continues:

> '[The] city's agencies have made major investments in diversifying the water supplies through activities such as: increase in surface and groundwater storage, purification and reuse of wastewater and collecting stormwater. They have also made substantial progress in reducing water demand. All these activities together have reduced the impact of drought. Yet we need to redouble our efforts to better prepare for the future; in particular, special attention should be directed towards more effective water pricing to encourage reductions in outdoor watering. Most Californians do not realize that landscape irrigation accounts for half of verbal warnings.

[48] http://news.yahoo.com/drought-exposes-cracks-australias-acclaimed-water-market-031900451.html

> California's agricultural powerhouse wonder has become increasingly vulnerable to drought. […] The challenges with these orchards have been for years that they need water every year. To make sure water is available for these crops during drought, farmers need to better manage their groundwater reserves and engage in more water trading.
> California's climate appears to be changing and becoming increasingly variable and warmer. Climate change models predict droughts like this latest one will be more frequent and more intense in the future. […] This means reducing demand and diversifying supplies. [The research shows that] California can adapt to even the most dire climate change predictions without major harm to our economy and our way of life. This will not be cheap or easy, but we can do it.'

The solutions that California has implemented are typical of the technical-approach category. California's government and water agencies are combatting drought via pricing, mandatory restrictions on outdoor watering, hotlines for reporting water waste and education classes for users (SCWC 2015). Therefore, based on the theoretical framework (Chapter 4), such means concentrate on the *conditioning rules* of normative practice. As stated in Chapter 1, if one approach comes alone, it falls short.

I am not as naïve to argue that the Australian or Californian policies are a success. However the Australian case[49] involves a sane and rational plan that is based on the prevailing national document, the National Water Initiative (NWI); now, after ten years, it is being reviewed.

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[49] The case is important in terms of societal characteristics. It covers an area that is twice the size of Spain and home to 40 percent of Australia's agricultural output.

Let us see how the thesis's framework functions for this case. In the brackets below, I refer to the rules of normative practice theory in order to show its value as a framework[50]:

> 'Over the past decade, the National Water Initiative [*see the structural rules of normative practice*] has guided water reform [*similar to the Mirab Company reforms*] across all jurisdictions and has led to increased efficiency and resilience [*refer to regulative/directional rules*] in the water sector. The reform has supported the development of a water sector that now gains *value* [*italics in original*] from water use and has begun to incorporate social and environmental values in its economic mechanisms. […] Progress on legislative reform [*refer to foundational rules; the new game is based on such reforms*] is varied across the jurisdictions; Western Australia and the Northern Territory, in particular, need to move ahead with their water legislation reform to progress in line with other jurisdictions. […] The National Water Commission has also identified that varied interpretations of objectives and guidelines have led to some inconsistencies across states. This requires attention and is especially important for water planning in the mining sector. To ensure the development of an equitable market and integrated system of management, all water uses should be managed within one framework [*refer to regulative/directional rules*]. Mining water use, in particular, needs to be integrated into current arrangements. Independent reviews of water plans and ongoing reform will be critical in ensuring all jurisdictions are meeting NWI objectives and that outcomes are beneficial for all user groups and the environment. This requires greater clarity about ecological objectives, supported by scientific evidence and ongoing assessment' (Lehane, 2015).

[50] For more general commentary on the normative practice framework, see Table 6.

In Table 8, I attempt to show that the forces causing the water governance failures are quite similar in all three cases, but that the cases tend to diverge when it comes to institutional governance. All three regions have suffered from competition between escalating demands and 'artificially enhanced supplies' (Burton, 1992). As the table shows, there are also similarities such as climate, increased river dryness, and conflicts among actors. However, it also shows that fewer problems have arisen in Australia than in Iran thanks to certain key conditions. For example, the newly enacted regulations known as the Nine-Point Agreement of Zayandehrud Basin are not yet operational. These create a new *foundational* rule that can make actors more coordinated; they also fulfil technical measures related to diversifying supply resources, purifying and reusing wastewater, and collecting storm water. By implementing the National Water Initiative, which allows water resources to support communities, ecosystems, and economic development, Australia benefits from coordination between the state and territory governments (NWC 2014).

The table's parentheses show how the relevant measures are applied to the approaches that I discussed in Table 1, page 22. None of them are directly linked to normative approach criteria. But again, some of the NWC's measures might well generate the rules of normative practice.

Table 8: A comparison of the Zayandehrud with two other cases in terms of problem-solving approaches

Problems	**Irn. Zyd***	**Cal. CCV****	**MD Aus.*****	**Measures*******	**Irn. Zyd**	**Cal. CCV**	**MD Aus.**
Drought and high temperature	*	*	*	Enacting new regulations and frameworks (managerial)	Nine-Point Agreement (not operational yet)	Sustainable Groundwater Act	National Water Initiative
Zero/cutbacks in water allocation	*	*	*	Coordinating actors (loosely normative)		*	*
Over-allocation	*	*	*	Diversifying supply resources (technical-economic)		*	*
Huge groundwater depletion	*	*	*	Setting up a market-based water trading system (technical-economic)			*
Climbing unemployment	*	*		Purchasing water rights (technical-economic and managerial)	*		*

Table 8 (continued): A comparison of the Zayandehrud with two other cases in terms of problem-solving approaches

Problems	**Irn. Zyd***	**Cal. CCV****	**MD Aus.*****	**Measures******	**Irn. Zyd**	**Cal. CCV**	**MD Aus.**
Farmer-Government conflict	*	*	*	Considering water rationing (managerial)	*	*	*
Low reservoir levels and wetlands drying up	*	*		Purifying and reusing wastewater and collecting storm water (technical-economic)		*	*
Landscape irrigation	*	*	*	Unbundling water rights (negotiated and normative)		*	

*Iran Zayandehrud **California Central Valley ***Murray-Darling of Australia **** current modes of problem-solving, refer to Table 1, page 22.

6.4. Limitations of the research

Other case studies may reveal additional causes behind water governance system failures. However, I have chosen to focus on these four causes, particularly I find the idea of normative practice so useful and compelling. Take, for instance, the *Mirab* practice's norms (Chapter 4) or other actors' norms (Chapter 5). Perhaps conflicts arise because these norms are interfered with; perhaps the norms themselves do the interfering. My thesis illustrates this idea, and it can deal with a practical issue. Why is this important? Wouldn't the engineer-as-practitioner instead want to deal with theoretical issues in practical ways? But having this theory in hand could help her realize how it works in practice.

In other words, my thesis basically identified some practical (and fundamental) issues in water management, and it argued that the theoretical model can reveal how to approach these issues in practice. However, there is also a limitation in the choice of research methods, both in the modelling (Chapter 2) and in the theoretical framework. This is because the normative practice theory gives us certain biases via over-complexification. We can speculate about other possible technical-analytical classic causes, such as modelling of drought's characteristics itself, population growth, recently record-high temperatures and increasing water demands, or reusing water scenarios to create more options; other research must ask how they function in practice and other settings. Additionally, the analytical model may rely on oversimplification, which 'is the bane of modeling' (Rescher, 2013).

I emphasized that the ethical framework of *normative practice articulates a set of guiding beliefs* – which apply to actors such as governments, major and minor water users, and citizens. Another limitation in the thesis stems from the fact that other beliefs and intentions may also play a role here. There are also causes that have clear links to actors' intentions: Molle (2008) makes some of these intentions clearer when he calls on decision-makers to devise mechanisms for stricter examination of planning hypotheses, more careful consideration of risk and greater transparency.

As stated in the introductory chapter, performing a proper comparative study is extremely difficult. The thesis results should be read in that light.

Therefore for analysing the new situation the documents about the actual practice were used which is impossible to do for the old practice because of time limitations and limited resources of a self-funded PhD thesis. Therefore, one might be in doubt whether the document-based analysis really reflects the real situation. We might see different intentions influence the water management practice. This is one of the difficulties of a comparative analysis that Hunt et al. (1976: 390) also reflects upon: it is difficult to work with general concepts (in the thesis case for instance: 'modernist ethos'), because they may have different meanings in different contexts. Therefore one may easily compare apples and pears; better would be to go back and forth between local case study and comparative efforts (in the thesis case this was not possible because of a lack of data). By referring to work by Millon and others (1962), Hunt et al. list a whole series of problems in comparative studies in water management. But the major issue is that the same terms in different documents (in the thesis case: historical vs. contemporary) may have different meanings and the comparison might deem invalid. Hunt et al. also state that choosing appropriate time periods for the research design and for establishing cause-and-effect relationships are important. For the abovementioned reasons I am not yet in a position to produce such a comparative study.

6.5. Future Research

The theory of normative practice is generic enough to shed light on the governance problems. Therefore, more research is obviously necessary to confirm that the normative approach can be applied properly in a variety of contexts. I have made five suggestions for future research that will extend the aims of this thesis.

a. In this thesis I used more subjective elements. Another line of research would be to apply an Actor-Network-Theory-perspective (Latour, 2005) to analyse non-human actors as well and to see whether the inclusion of non-human actors would provide additional insight in water governance.

b. The OECD has developed principles of good water governance (OECD, 2015_a). This framework for multi-level governance is more or less the standard now in water management (OECD, 2015_b). In this report, several 'governance gaps' are identified. In future, it would be useful to recognize how the new approaches compare to the OECD approach and what their specific merits are.

c. In her paper on Arrow's Impossibility Theorem, Ostrom (2007) acknowledges three levels of rules in the institutional analysis and development (IAD) framework. She names them operational, collective-choice and constitutional-choice rules. It would be interesting to compare Ostrom's three levels of IAD with the normative practice framework rules within the context of complex water management[51].

d. Another research topic could be formulated more generally. I have used a framework that has its basis in normative ethical theory. The OECD and

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[51] This is based on the informal discussions with Shafiqul Islam in the Water Diplomacy Workshop, 2015.

Ostrom's model come from the governance literature, which is more empirically oriented; Islam and Susskind have proposed the Water Diplomacy Framework (WDF). Future research might compare this conceptual, normative approach with models derived from the governance literature to see whether, and if so how, they can complement each other.

e. I have not said much about society-related terms and theories. However, new scholarship addressing water infrastructures as socio-technical systems might spring from the work of Rittel and Webber (1973). In the framework of the General Theory of Planning, they identify problems of social policy as 'wicked' problems. They acknowledge that 'there is no definitive formulation of a wicked problem' (Rittel and Webber, 1973: 161); can the notion of a wicked problem be applicable to the water management domain, and if so how?

6.6. A short epilogue

A few years ago, there was a nearly universal consensus that a centralized mode of water management was appropriate for every developing plan in which all actors might be winners. That consensus has eroded. I have shown that such multipractice phenomenona should be reshuffled by using normative criteria – by creating new (local) values – that make them more beneficial for human society and nature, and less harmful. Normative practice is a culture, and without that culture, practice will have none of humanity's values. Thus the more we investigate this area of normative approach, the more our professional procedures and patterns become oriented toward morality.

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Summary

Iran's Zayandehrud hydrosystem is suffering from over-building and over-allocation caused by conflicting governance patterns, tools, engineering models and methods, and technological means. This thesis focuses on the actors in this socio-technical actor network. I argue that understanding the failure of the Zayandehrud governance system requires attention not only to technical and managerial issues, but also to actors' interests and norms and values. Rather than looking at the issues from a strictly technical point of view, this project also describes them as normative phenomena. Therefore, this thesis employs the normative practice framework from philosophy of technology and ethics to discover the inherently normative dimensions of actions, and to analyse norm-related conflicts within and among actors.

I begin with an introductory chapter that discusses the case study at hand, reviews scientific reflections on the issue, and also identifies both the problem and the gaps (related to theory and practice) that will be filled. The introduction links these issues with the fields of water governance, ethics and philosophy of technology.

Chapter Two uses the Dichotomous Markov Noise (DMN) model, with nonparametric test application (with constant transition rates), to describe the dynamics of fluctuation in the river's water level as a stochastic process that is imposed on changes in river discharge. In this chapter, I identify two different regimes for the long-term behaviour of the Zayandehrud River. Based on these regimes, I define two nonparametric classes of long-term increasing or decreasing water levels, which are separated by an exponential steady state regime. In this chapter, I develop a nonparametric testing procedure to test exponentially (the river

steady state regime) against an overall decreasing level distribution. The proposed test depicts the long-term regime behaviour of the river. The mathematical tools introduced to handle the problem are suitable for more general use, and the testing procedure provides a new tool for the study of water level dynamics. Under conditions of data austerity and as a case study, I also examine the stochastic characteristics of the river water level.

Chapter Three argues that the water governance may fail if we neglect the past engineering skills. Hydraulic heritage systems, both underground and exposed, have been known to be sustainable for millennia. Persian and Roman aqueducts, as well as Dutch polders, are examples of such hydrosystems. Their advantages, while often overlooked, are undeniable: they are functionally interconnected with surrounding societal and ecological systems, which sometimes leads to revitalization plans. By using the notion of the 'qualifying role,' Chapter Three raises questions concerning the disregarded functions and early and historical positions of Qanats as hydraulic heritage systems. It does so via a problematic case study in Iran, in which the construction of a drainage system modelled on a bygone socio-technical system's techniques resulted in a dramatic drawdown in the water level of the area soon after construction. This chapter illustrates the 'qualifying role' of Qanats in urban drainage by describing the skill involved in their governing, planning and construction. Thus I address the forces that underlie technological traditions as backward-learning processes.

Chapter Four applies the normative practice model to the domain of water management as a case study. Since current water governance patterns require cooperation and partnership within and among the networks of actor-, supplementary concepts are necessary to distinguish the roles and the rules of actions, which is why the thesis extends normative practice in the framework of philosophy of technology. Following a modern holistic analysis, the chapter illustrates how values implicit in water apportionment mechanisms are being reshaped. Chapter Four, by using the theory of normative practice, scrutinises the tasks and the rules of the old and new water management systems, or *Mirab*. Subsequently, according to this philosophical theory, the chapter argues that conflicts pertaining to these cases are due to interference among relevant structural and directional norms.

Chapter Five further elucidates and classifies different actors' norms, analysing them to show where the conflicts and the friction spots are. The water conflicts arise when there are disagreements among actors' norms and what is seen or deemed by actors as a wrong measure. In the analysis section, I discuss the cause of a problem that originated in different norms becoming mixed. According to normative practice theory, such conflicts are due to interference among structural and directional norms relating to the actors' tasks and interests.

Samenvatting

Het Iraanse *Zayandehrud* watersysteem heeft te lijden van een te veel aan bebouwing en aan overexploitatie, problemen die verder versterkt worden door tegenstrijdigheden in het beleid en het (verkeerd) gebruik van technische modellen, methoden en middelen. Dit proefschrift is gericht op de analyseren van de actoren in dit socio-technische systeem. Er wordt betoogd dat het begrijpen van het falen van het *Zayandehrud* watersysteem niet alleen aandacht vereist voor technische en bestuurlijke oorzaken, maar ook vraagt dat gekeken wordt naar de normen en waarden van de betreffende actoren. In plaats van te kijken naar de problemen vanuit een strikt technisch oogpunt, ziet dit onderzoek het probleem ook als een normatief verschijnsel. Daarom maak dit proefschrift gebruik van het normatieve praktijkbegrip uit de (reformatorische) filosofie van de technologie. Zodoende beoogt het om de inherente normatieve dimensies van handelingen te analyseren en te wijzen op conflicten in waarden van, en tussen actoren.

Het proefschrift begint met een inleidend hoofdstuk en introduceert de specifieke case studie die centraal staat. Er wordt ingegaan op de probleemstelling, de vraagstelling, de wetenschappelijke relevantie en de bijdrage aan vakgebied water governance.

Hoofdstuk twee vormt een illustratie van het gebruik van technische modellen in het waterbeheer. In dit hoofdstuk wordt een stochastisch model ontwikkeld voor een Decision Support Systeem (DSS). Met dit model kan het real time gedrag van de *Zayandehrud* rivier gemodelleerd kan worden. Het model is gebaseerd op de Dichotome Markov Noise (DMN) benadering, dat op een niet-parametrische wijze de dynamiek van fluctuaties in het waterniveau kan beschrijven als een stochastisch proces. Gegeven de onzekerheden en de ‘randomness’ in de rivierafvoer is een

stochastisch model beter in staat om het lange-termijn gedrag van een rivier te voorspellen dan een deterministisch model. Door toepassing van dit model en het analyseren van de data van de rivier *Zayandehrud* worden twee verschillende regimes bepaald voor het gedrag van de rivier op lange termijn. Het ontwikkelde model kan worden beschouwd als een nieuw wiskundig hulpmiddel in de studie van waterniveaudynamiek, dat in een situatie van beperkte beschikbaarheid van gegevens inzicht kan geven in het gedrag van een rivier, op basis waarvan de technische besluitvorming ondersteund kan worden.

In hoofdstuk drie wordt betoogd dat de problemen met de rivier *Zayandehrud* deels zijn geworteld in een verwaarlozing van historische technische vaardigheden. Het is bekend dat sommige hydraulische erfgoedsystemen al gedurende millennia duurzaam functioneren. Perzische en Romeinse aquaducten, maar ook Nederlandse polders zijn voorbeelden van dergelijke systemen. De waarde van dergelijke systemen wordt vaak over het hoofd gezien, maar ze hebben onmiskenbare voordelen: ze hebben een functionele verbondenheid met de hun omringende samenleving en de natuur. In hoofdstuk 3 wordt dit begrepen met behulp van de notie van 'qualifying role'. Hoofdstuk drie stelt in het bijzonder vragen over de tot op heden genegeerde functies van de Qanat als voorbeeld van een hydraulisch erfgoedsysteem. Dit komt naar voren in problematische case studie in Iran, waar de bouw van een drainagesysteem heeft geleid tot een dramatische terugval in het waterpeil van het gebied snel na de bouw. Dit hoofdstuk illustreert de 'qualifying role' van Qanats in stedelijke drainage.

Hoofdstuk vier past het normatieve praktijk model toe op de casus van de rivier *Zayandehrud*. Aangezien het huidige waterbeheer samenwerking en partnerschap binnen en tussen de actoren in de waternetwerken vereist, zijn aanvullende theorieën nodig die de strikt technische benadering complementeren. Om die reden maakt het proefschrift gebruik van het normatieve praktijkbegrip uit de (reformatorische) filosofie van de technologie. Het hoofdstuk laat zien hoe de waarden voor waterdistributie veranderen. Met behulp van de theorie van normatieve praktijken wordt onderzocht wat de taken en de regels in de oude en nieuwe watermanagementsysteem, de *Mirab*, zijn. Vervolgens wordt beargumenteerd dat in de lijn met de filosofische theorie, de optredende conflicten het gevolg zijn van de interferentie van structurele en directionele normen binnen de betreffende praktijk.

Hoofdstuk vijf maakt een nadere analyse van de normen van de actoren, zowel om wat voor type normen of regels het gaat (volgens de theorie van normatieve praktijken) alsook een analyse van de conflicten tussen de verschillende normen. Voor de casus van het *Zayandehrud* hydrosysteem wordt geanalyseerd waar er sprake is verschillen tussen de bestaande normen en wat wordt gezien als goed en fout door de actoren. Er wordt ingegaan op de oorzaak van het probleem dat ontstaat als verschillende normen gecombineerd worden of vermengd raken. In lijn met de normatieve praktijktheorie wordt betoogd dat de conflicten ontstaan als gevolg van de interferentie van structurele en directionele normen onderling, en met de taken en de belangen van actoren.

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A Note on the Author

Mehdi Fasihi Harandi (1972) was born in Kerman, Iran. He grew up and went to school in Isfahan, studied Irrigation Engineering at Isfahan University of Technology, (1995), and continued at Amirkabir University of Technology (Tehran Polytechnic), where he received a M.Sc. in Civil Engineering (1998). He worked for several years as an engineer, project manager and CEO before starting his PhD studies in September 2011. He was affiliated to Delft University of Technology and consultant engineering company PayandAb Tavan of Iran as a PhD researcher in the field of Policy analysis, water governance, ethics and philosophy of technology. The results are presented in this dissertation. He is married to Sepideh, has two children (Ali [14] and Aye [2]) and lives in Isfahan, Iran.