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HANDLING FUTURE UNCERTAINTY - STRATEGIC PLANNING FOR THE INFRASTRUCTURE SECTOR

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DAMIAN DOMINGUEZ

Dipl. Umweltingenieur ETH Zurich

born 31.01.1979

citizen of Muttenz / BL and Lupsingen / BL

accepted on the recommendation of

Prof. Dr. Willi Gujer, examiner
Prof. Dr. Volker Hoffmann, co-examiner
PD Dr. Bernhard Truffer, co-examiner

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Summary

The technical components of infrastructure systems are planned and designed to operate over time periods of 25 to 40 years. However, the context conditions under which an infrastructure organization operates can change drastically and unpredictably over this extended time frame, due, for example, to population developments, new regulations or emerging technologies. Several studies on the future of infrastructure sectors have recently raised doubts regarding the capacity of the public sector to adequately address this future uncertainty and secure the delivery of infrastructure services. Prominently, private sector participation has been proposed as an option to address this capability gap.

This thesis argues that public utility organizations can identify suitable alternatives to close this capability gap and thus improve their handling of future uncertainty by applying adequate management principles, such as formal strategic planning. Privatization is therefore not a necessary precondition for ensuring the long term delivery of utility services. This however requires an adaptation of existing strategic planning approaches to the particularities of the infrastructure sector, primarily 1) the high degree of path dependencies constraining the set of viable alternatives 2) the long planning horizons (and the related future uncertainty) and 3) the variety of environmental, social, economic and governance objectives imposed on the sector.

To test this hypothesis, existing strategic planning approaches in the infrastructure sector were analyzed and a series of requirements for a strategic planning, suitable for the infrastructure sector, were developed. Based on this analysis, a strategic planning approach which complements the existing methodologies was developed and applied in three representative case studies in the Swiss wastewater sector. This approach builds on methods such as scenario planning and focuses on a structured debate, where possible future developments, available alternatives, and pursued objectives are explicitly addressed and evaluated from different perspectives.

The application of the strategic planning approach shows that, given adequate tools, public utility organizations can overcome their limitations in identifying capability deficits regarding future challenges and assess adequate strategies to address these deficits. In addition, the strategic planning process stimulates a learning process within the organization. However, the selected strategies depend on value judgments and the existing organizational forms prevalent in the respective regions. This result suggests that an increasing diversity of organizational forms, i.e. ones which integrate various elements of private or public organizations, is likely to develop over the coming years.

Zusammenfassung

Infrastrukturanlagen werden heutzutage für eine Lebensdauer von 25 bis 40 Jahren geplant und dimensioniert. Während dieser langen Zeitspanne sind Infrastrukturen starken Dynamiken ausgesetzt, die einen massgeblichen Einfluss auf deren Betrieb haben. So ändern sich etwa die Bevölkerung im Einzugsgebiet, die gesetzlichen Vorgaben und die technologischen Möglichkeiten. In verschiedenen Studien zur Zukunft von Infrastrukturen wird jedoch an der Fähigkeit der öffentlichen Hand gezweifelt, diese Dynamiken adäquat zu berücksichtigen und eine langfristige Gewährleistung von Infrastrukturdienstleistungen zu garantieren. Ein oft diskutierter Vorschlag zur Begegnung dieser Grundproblematik ist eine stärkere Beteiligung von privaten Unternehmen in Infrastruktursektoren.

In dieser Dissertation wird ein Alternativweg vorgeschlagen. Es wird argumentiert, dass öffentliche Infrastrukturunternehmen durch die Anwendung von Managementansätzen wie Strategische Planung durchaus in der Lage sind, geeignete Strategien zu entwerfen, um mit Zukunftsunsicherheit umzugehen. Hinsichtlich der Besonderheiten in Infrastruktursektoren bedarf es jedoch einer Anpassung der vorhandenen Ansätze zur strategischen Planung. Besonders zu berücksichtigen wären 1) der Grad an Pfadabhängigkeiten im Hinblick auf die Bewertung von Alternativen, 2) die langen Zeithorizonte und die damit verbundene Zukunftsunsicherheit und 3) die Bandbreite an Zielen (Umwelt-, Sozial-, Wirtschafts- und Steuerungsziele), der ein Infrastrukturunternehmen Rechnung zu tragen hat.

Die Gültigkeit dieser Hypothese wurde in mehreren Schritten überprüft. Der erste Schritt umfasste eine Analyse von vorhandenen Ansätzen zur strategischen Planung im Bereich von Infrastruktursektoren und deren Einschränkungen. Von dieser Analyse ausgehend wurde ein ergänzender Ansatz zur strategischen Planung entwickelt und in drei Fallstudien im Schweizer Abwassersektor angewendet. Der entwickelte Ansatz basiert auf etablierten Methoden wie die Szenarioanalyse und fokussiert auf eine systematische und offene Diskussion von vorhandenen Zukunftsunsicherheiten, Alternativen und verfolgten Zielen unter Berücksichtigung verschiedener Blickwinkel.

Die empirische Anwendung des entwickelten Ansatzes zeigt, dass öffentliche Infrastrukturorganisationen in der Lage sind, zukünftige Herausforderungen und deren Konsequenzen für die Organisation zu identifizieren und geeignete Strategien zu erarbeiten. Die bevorzugte Strategie hängt jedoch von der Ausgangslage der Organisation ab, insbesondere deren Zielrichtungen und der daraus resultierenden Evaluation vorhandener Alternativen. Dies lässt in der Zukunft eine grössere Bandbreite an Organisationsformen in Infrastruktursektoren erwarten, in der öffentliche und privatwirtschaftliche Prinzipien kombiniert werden.

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Introduction

Industrialized countries built up most of their infrastructure systems between 1950 and 1980 following a civil engineering logic. This approach ultimately led to the development of a system characterized by centralized and capital intensive technical structures, planned and designed to operate over a time period of 25 to 40 years (Markard and Truffer 2006). While the technical aspects of this system have reached a high degree of refinement, management aspects have been largely neglected. The latter applies especially to publicly owned utility organizations, the dominant organizational form worldwide. Consequently, public utilities often lack the necessary capabilities for handling long-term developments, a critical deficit in view of the extended life span of utility systems. Over a period of 25 to 40 years the environment of a utility organization can change drastically and unpredictably. Unforeseen changes such as new regulations, shifting economic conditions or improving technologies are not uncommon and may require costly adaptations in the operation of a utility.

The central theme of this thesis is how the public infrastructure sector can identify and select adequate strategies for handling future uncertainty and thus ensure the long-term delivery of utility services. The main contribution of the thesis is twofold. First, it frames current approaches to handling future uncertainty. Second, it demonstrates that adequate strategic planning can help public utilities overcome their limitations in identifying and compensating capability deficits relevant when facing future uncertainty.

1. Problem Setting

Particularities of the infrastructure sector: Path dependencies and multiple objectives

Infrastructure sectors such as water supply, sanitation or electricity supply are characterized by a number of particularities relevant to their ability to address future uncertainty. First, the alternatives available to address future developments are strongly limited by the existing technical and organizational structures. Infrastructure systems exhibit a high degree of path dependency, and consequently changing context conditions are addressed preferably by incrementally adapting the existing infrastructures (see Dominguez and Gujer 2006; Tillman et al. 2005). Second, utilities bind resources for decades to come, as they usually consist of sizeable, capital intensive physical infrastructures (e.g. widespread networks, large plants). Third, the objectives imposed on infrastructure services are typically multidimensional. Utility organizations have to fulfill a variety of non-complementary objectives such as compliance with legal requirements, complete service provision at low costs and cost-effective provision of service. Finally, the public sector has played, and continues to play, an important role in the development and operation of the infrastructure system. As a consequence, political considerations often influence the type of alternatives evaluated when addressing future uncertainty.

Changing perception towards future uncertainty

Awareness of the need for explicit consideration of long term future uncertainty in the infrastructure sector is relatively new. Industrialized countries built up most of their infrastructure system between the Second World War and the 1980’s. During this building phase, future context conditions were regarded as stable or predictable (Dyner and Larsen 2001), a defendable working assumption at that time. There was no real need for sophisticated handling of future uncertainty, as the constant enlargement and upgrading of the infrastructure system characterizing the phase provided the system with a high degree of flexibility to adapt to changing context conditions.

However, given the impending refurbishment of the infrastructure system in industrialized countries, awareness is growing that a different approach to future uncertainty will be needed. The further development of the infrastructure system will differ significantly from the original building phase, since both the degrees of freedom in the infrastructure system and the degrees of future uncertainty have changed. First, today the degrees of freedom are limited by the existing, no longer growing, infrastructure system. Second, the degree of future uncertainty seems to have increased since the end of the building phase. Context conditions over the next 20 to 30 years are becoming more and more uncertain due to emerging challenges such as massive investment needs, changing regulations, rapid urbanization and market liberalization (OECD 2006; OECD 2007; UN-HABITAT 2006). Compounding this, the criteria by which infrastructure organizations will be evaluated in the future will also become increasingly uncertain. For almost one hundred years, infrastructure organizations were optimized to guarantee the provision of effective, homogeneous and affordable services. However, valuation criteria like economic efficiency and sustainability are currently gaining predominance in the public discourses (Hirsh 1999; Gray 1998; Wilderer 2004). In addition, there is an increasing demand for citizen participation in infrastructure related issues (see e.g. OECD 2007; Pahl-Wostl 2005), which is likely to increase the diversity of valuation criteria.

Doubts in the capacity of public sector to handle future uncertainty

The capacity of the public sector to identify and select alternatives to deal with this future uncertainty and ensure a long term provision of service has been questioned by several studies (Kelman 2007; OECD 2006; OECD 2007; UNESCO / World Water Assessment Programme 2006; Urban Land Institute and Ernst & Young 2007). Worldwide, this has given rise to fundamental sector reform initiatives aiming at privatization, liberalization and deregulation of the sector (Andrieu 2007). However, attempts to fully privatize utilities have experienced strong political opposition in many parts of the world and are therefore, not always considered a viable alternative. There is therefore a need for alternative approaches to assist public utilities in the identification of both deficits hindering the handling of future uncertainty and measures to compensate for these deficits.

2. General research questions and approach

This thesis argues that public utilities can identify the capabilities required to deal with future uncertainty and select adequate measures for the development of these capabilities by applying adequate management principles, for example strategic planning. Strategic planning is understood as a systematic process leading to the identification of both external developments affecting the organization and the possible alternatives needed to face these developments. Although strategic planning is a key concept in management contexts, it has no tradition in the infrastructure sector, and there are few examples explicitly addressing the particularities of the infrastructure sector (see AWWA Research Foundation 2005, Mugabi et al. 2007 for some exceptions).

Aim of this thesis was therefore to investigate the potential of strategic planning when handling the future uncertainty faced by a utility organization. The focus was set on wastewater utilities, as it can be regarded as a representative example of utility sectors with highly localized structures, dominant public organizational forms and a high public sensitivity.

The following questions were addressed in this process:

- What existing strategic planning approaches are used in the infrastructure sector? How do they handle uncertainty?

- What requirements should a strategic planning approach suitable for the infrastructure sector fulfill?
- Can public utilities identify adequate strategies for handling future uncertainty?

In a first step to answer these questions, the limitations of existing perspectives on strategic planning in the infrastructure sector were analyzed and a strategic planning approach complementing these limitations was developed. This required widening the prevalent engineering view of the problem to include tools and approaches from both social and management sciences. In a second step, three representative case studies were conducted in the Swiss wastewater sector in which the suitability of the proposed strategic planning approach was tested and the results of its application analyzed (a detailed account of the representativeness of both the case studies and the Swiss wastewater sector can be found in chapter 2).

3. Thesis outline and summary of results

The thesis is structured as a paper dissertation. The chapters have been submitted for publication to different journals and can be read independently of each other. Consequently some arguments are repeated throughout the different chapters.

Chapter 1 sets the frame of the thesis. It analyzes the existing perspectives on handling future uncertainty in the infrastructure sector and proposes an additional perspective on this task. This chapter shows that existing strategic planning perspectives possess a series of limitations. These relate to how future uncertainty is characterized, the set of alternatives evaluated when facing this uncertainty and the consideration of objectives and trade-offs. In order to overcome these limitations an additional discursive perspective, based on qualitative approaches such as scenario planning, is proposed. A corresponding strategic planning approach is introduced and illustrated with a case study in the Swiss wastewater sector.

Chapter 2 presents and compares the results of the application of the proposed strategic planning approach in the three representative case studies and discusses the consequences of the results. The empirical data strongly suggest that adequate strategic planning helps public utility organizations in the identification of capability deficits related to future challenges and measures to address these deficits. In addition, the strategic planning process stimulates learning within the organization. By this, the argument that only privatized utilities can identify and implement the capabilities required to face future challenges can be dismissed. Additionally, this chapter also shows that the results of the strategic planning process depend strongly on value judgments and existing organizational forms, which suggests that in the coming years an increasing diversity of organizational forms will arise in the infrastructure sector.

While the first two chapters contain the key findings of the dissertation, the last two complement and elaborate the analysis conducted in Chapter 1. **Chapter 3** was written for the engineering community and illustrates the limitations of the traditional (adaptive) perspective to strategic planning in the infrastructure sector, which relies on the prediction of future context conditions. In this chapter, the degree and impact of future uncertainty on an infrastructure system is exemplified using an empirical example from the wastewater sector. In this case study the historical development of a wastewater treatment plant is analyzed over a period of 14 years and compared with the original design parameters. Chapter 3 shows that the range and impact of unforeseen changes in the context conditions of a utility organization go far beyond the range that could reasonably be expected in the context of traditional engineering approaches. It concludes that infrastructure organizations would profit from a more systematic account of future uncertainty.

Finally, **Chapter 4** complements the first chapter by illustrating the application of scenario analysis- the key element of the proposed strategic planning approach- in a utility organization. As the use of scenario analysis in the infrastructure sector is rare, we focus in this chapter on illustrating the different steps of the methodology employing a case study. In the context of this thesis the paper underlying this chapter is used for purely illustrative purposes. However, the leitmotif of the paper relates to methodological assessment of the degree of flexibility that a wastewater treatment plant will require in order to adapt to future developments. The paper advocates the use of scenario analysis as a systematic approach to framing the relevant factors that influence the long term development of a utility and assessing the characteristics of the required flexibility.

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Chapter 1

Tackling uncertainties in infrastructure sectors through strategic planning- The contribution of discursive approaches in the urban water sector

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Tackling uncertainties in infrastructure sectors through strategic planning- The contribution of discursive approaches in the urban water sector

Damian Dominguez[1,*], *Bernhard Truffer*[2], *Willi Gujer*[1]
*Corresponding author
[1] Engineering Department, Swiss Federal Institute of Aquatic Science and Technology, Eawag, 8600 Dübendorf, Switzerland and Institute of Environmental Engineering, ETH Zurich, 8093 Zurich, Switzerland
(damian.dominguez@eawag.ch; gujer@eawag.ch)
[2] CIRUS Department, Swiss Federal Institute of Aquatic Science and Technology, Eawag, 8600 Dübendorf, Switzerland (bernhard.truffer@eawag.ch)

Abstract
Several strategic planning approaches have been proposed for dealing with future uncertainties in the urban water infrastructure sector. We identify three well established perspectives that address uncertainties in strategic decisions: an adaptive perspective, focusing on an incremental adaptation of existing structures as a reaction to unforeseen developments, a modeling perspective, focusing on an improved characterization of future context conditions and a managerial perspective, focusing on increasing the flexibility of the infrastructure organization. Despite their virtues, these approaches have definite weaknesses in their approach to uncertainty: they often consider a restricted scope of alternatives, they face substantial difficulty to predict context conditions over time periods of decades, and mostly only implicit consider objectives and tradeoffs. We elaborate in the paper a fourth, discursive perspective that may compensate for the specific weaknesses of the other approaches. This fourth perspective is based on a discursive, qualitative assessment of key elements in the strategic planning process among a selected set of local stakeholders and decision makers. We illustrate our approach by presenting results from a case study in the Swiss wastewater sector. We maintain that this approach leads to a more explicit and reflected treatment of future uncertainty, conflicting objectives and a broadening of the considered alternatives. By this it supports the formulation of more robust strategic decision making. We finally argue that the discursive approach is an important complement to the established strategic planning approaches, and a necessary element for ensuring the long term provision of services in infrastructure sectors.

Keywords: Strategic planning, future uncertainty, infrastructure, wastewater, scenario analysis, foresight

1 Introduction

Urban water infrastructure has played a key role over the past decades in improving the environmental, economical and social standards worldwide. Today's achievements in water protection would for example be unthinkable without the service provided by wastewater treatment plants. However, the capacity to deliver these services in a sustainable, i.e. long term secured way is being challenged by several developments.

The urban water management sector, like most infrastructure sectors in industrialized countries, was built based on a rather narrow socio-technical paradigm mostly defined by engineers. This paradigm favored the construction of centralized and capital intensive physical infrastructure (e.g. widespread networks, large plants) with clearly defined tasks (e.g.

drinking water provision, wastewater treatment) built to operate over a time period of decades (Markard and Truffer 2006). The implementation of this paradigm relied on very specific assumptions about future developments and the objectives of an infrastructure organization. It was assumed that the socio-economic development of the corresponding region could be predicted over decades with sufficient precision. Additionally, the provision of effective, homogenous and affordable services was regarded as the main objective of an organization operating an infrastructure system.

However, evidence suggests that although these assumptions were more or less defendable in the 70’s and 80’s (and mainly only for industrialized countries), they will not necessarily be equally valid in the future. Infrastructure organizations are confronted nowadays with an increasing amount of future uncertainty, the urban water sector being no exception. Herder and Verwater-Lukszo (2006) derived from Walker (2000) two types of future uncertainty: context and valuation uncertainty. Context conditions over the next 20 to 30 years are becoming more and more uncertain due to emerging challenges such as massive investment needs, changing regulations, rapid urbanization and market liberalization (OECD 2006, 2007; UN-HABITAT 2006; UNESCO / World Water Assessment Programme 2003, 2006; Urban Land Institute and Ernst & Young 2007). On the other side, the criteria by which infrastructure organizations will be valuated in the future are also becoming increasingly uncertain. An ongoing intensive political debate has fundamentally questioned the goals of successful infrastructure management. For almost one hundred years, infrastructure organizations were optimized to guarantee the provision of effective, homogeneous and affordable services. Since the early 90ies, economic efficiency has gained predominance in the public discourses (Hirsh 1999; Gray 1998) and privatization was considered the best means to achieve this goal.

This increasing future uncertainty has important consequences for the long term provision of water and sanitation services, as the responsible decision makers often lack the necessary know-how for its handling. Worldwide, the provision of water-related services is usually a public sector function, organized at the municipal level (Aubin and Varone 2007; Pinsent Masons 2007). Municipalities are therefore not only responsible for the maintenance of the infrastructure system but also decide on its future development. However, recent studies have questioned the capacity of public organizations to handle both context and valuation uncertainty (OECD 2006; OECD 2007; Urban Land Institute and Ernst & Young 2007)**.** While the technical components of the infrastructure system have reached a high degree of refinement over the past decades, organizational, financial and especially strategic aspects have been largely neglected. The lack of these competencies is particularly daunting in strategic decision making contexts, i.e. when the long term uncertainties related to challenges, objectives and alternative system configurations have to be considered.

Strategic planning has been proposed as a tool to aid urban water organizations in the development of key competencies and the identification of alternatives on how to handle both context and valuation uncertainty (Dominguez et al. 2009). Recent literature provides different strategic planning approaches and tools capable of supporting the strategic planning process like e.g. modeling tools, real option approaches and decision analysis (see e.g. Dyner 2000; Dyner and Larsen 2001; Gil 2007; Heinrich et al. 2007; Zhao et al. 2004; MacGillivray et al. 2006)**.** However, both the strategic planning approaches and the tools favored vary strongly depending on the disciplinary background of the authors. Most of these proposals may be attributed to one of three perspectives: an adaptive, a modeling and a managerial perspective. The adaptive perspective to strategic planning represents the currently dominant approach in the engineering practice. It deals with future uncertainty by betting on the most probable development of context conditions (mostly in a business-as-usual type of forecast). Deviations from this prediction have to be compensated by incremental adaptation of the installed infrastructures. The modeling perspective focuses on an improved characterization respectively prediction of the future uncertainty faced. The managerial perspective focuses on increasing the flexibility of the infrastructure system to improve its capacity to accommodate change.

In this paper, we discuss the applicability and limitations of these perspectives with regard to their approach to context and value uncertainties. We argue that these weaknesses can be compensated by a fourth, complementary perspective. This perspective builds on informed discourses among experts and stakeholders concerning available alternatives, pursued objectives and possible future context conditions, while explicitly addressing tradeoffs and the diversity of interest positions.

The paper proceeds as follows. In the next section, we will classify the strategic planning approaches in infrastructure sectors into the three perspectives. The literature review is by no means exhaustive, but rather aims at framing the problem. Drawing on recent experiences in environmental governance, we then propose a fourth perspective to strategic planning in the urban water infrastructure sector and introduce a corresponding strategic planning approach. We will then illustrate the different procedural steps of the strategic planning approach with the aid of a case study in the Swiss wastewater sector. In the discussion, we expand on the contribution of the proposed perspective, discuss how the different perspectives can complement each other and explore the transferability of the lessons gained to other infrastructure sectors.

2 Strategic planning in the urban water sector

2.1 Context

Strategic planning is understood here as a process aiding the infrastructure organization in the identification of both long term external developments affecting the organization and the possible alternatives to face these developments. In accordance with the operational life of infrastructure, this process should address time frames of 20-30 years. Goal of the process is not to elaborate specific problem solutions but rather to reach a shared understanding among different parties about the longer term priorities of an organization (Grant 2003; Schoemaker 1992).

Strategic planning for such long time periods and for sectors with a strong role of public organizations has received little attention in academic literature, so far (Dominguez et al. 2009). Existing approaches usually aim at enhancing the service performance over time periods of five to ten years (see e.g. Mugabi et al. 2007; Rothstein 2003). Tillman et al. (2005) analyze two major past conditions in the urban water infrastructure sector that may explain this lack of attention. First, over the past decades the sector had been operating under stable and predictable conditions. Second, in the past, adaptation costs played an unimportant role, as they could be integrated into the development and expansion of the infrastructure system. The past century was dominated by the construction and enlargement of the infrastructure system. In this building phase it was relatively uncomplicated to adapt to changes in the context conditions.

2.2 Perspectives for handling future uncertainty

As a consequence of the increasing future uncertainty in the infrastructure sector, the awareness for the need for an adequate strategic planning is increasing (Dyner and Larsen 2001) and different approaches have been proposed over the years. We propose that the approaches found in the literature may be attributed to one of three perspectives: an adaptive, a modeling and a managerial perspective (see Figure 1).

The predominant approach to strategic planning in infrastructure sectors follows the adaptive perspective. Future socio-economic context conditions are considered by incrementally adapting the existing infrastructure (see Dominguez and Gujer 2006; Tillman et al. 2005). This adaptation takes place within the system boundaries defined by the conventional socio-technical paradigm. That is, the range of alternatives to face future uncertainty is limited to the highly localized, centralized physical infrastructure and a rather narrow organizational paradigm (see e.g. Priemus 2007). Additionally, external developments affecting the operational life of the infrastructure (population, requirements, etc.) are considered through models providing forecasts on the basis of past developments and current trends (Markard and Truffer 2006; Goodman and Hastak 2006). On the other hand, the objectives of the organization are regarded as externally given (e.g. compliance with a legal standard) which can best be assessed by technical experts.

The adaptive perspective may be regarded as adequate as long as the uncertainty regarding future developments remains low, an effective provision of service is the main objective and additional costs induced by adaptations can be covered by increasing tariffs (Dyner and Larsen 2001). As these conditions applied in the past for many countries, most of today's infrastructure was successfully built according to this perspective. Due to increased uncertainties in context conditions and objectives to consider, the conventional perspective has mostly been enlarged in two different directions. One focusing on improving the characterizations of future developments (modeling perspective) and the other one on expanding the system boundaries for choosing appropriate technical solutions (managerial perspective) (see Figure 1).

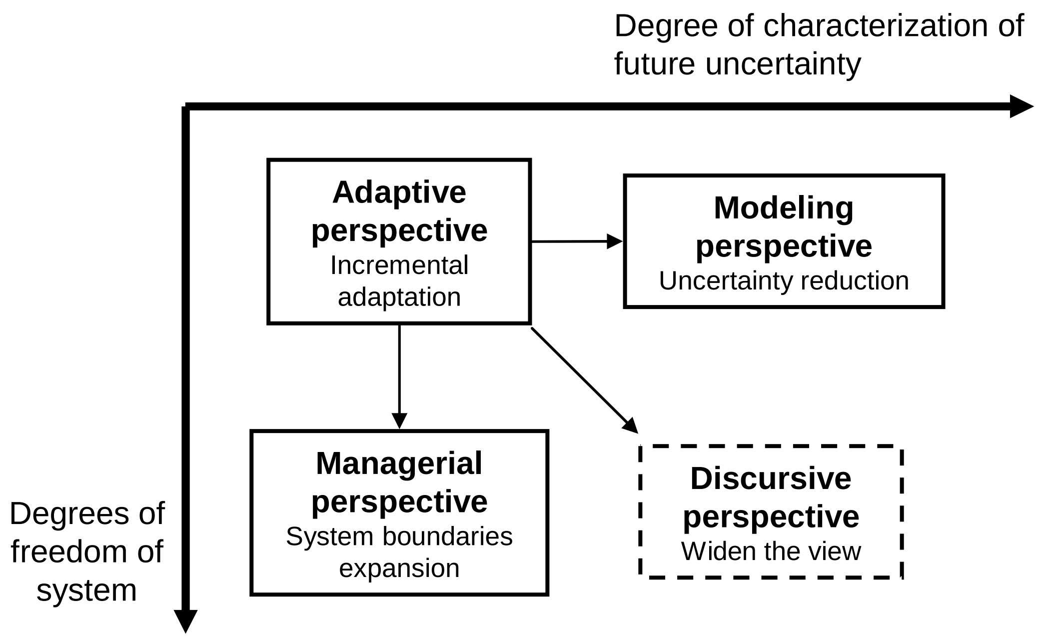

Figure 1 Existing perspectives to handling future uncertainty and shifting objectives. We propose a fourth perspective focusing on a qualitative, structured discussion of the future uncertainty faced, the available alternatives and the pursued objectives (dotted box)

The modeling perspective assumes the system boundaries of the conventional socio-technical paradigm (local, centralized structures, clear defined tasks) as given and aims at reducing or quantifying the uncertainty present in predictions of the future. Objectives are regarded as externally given and subject to technocratic valuation. Reduction respectively quantification of the future uncertainty takes place by either enhancing the quality of the models extrapolating past developments (see e.g. Gifford 1993; Wilken et al. 1998) or by increasing the understanding of the interdependencies in the external environment and their consequences for the infrastructure organization (see e.g. Malmqvist 2007). Dyner and Larsen 2001) provide an overview of tools available for the latter, ranging from agent based modeling to scenario analysis. The obtained information can then be integrated into the planning and design of the physical infrastructure. For example, Rachmatullah et al. (2007) evaluated the upgrading plans for electricity infrastructure in Indonesia against the background of the uncertainty range depicted by future demand scenarios. In the same sense, Zhao et al. (2004) developed a stochastic model for accounting long term uncertainties in highway development.

By contrast, the managerial perspective assumes that future conditions cannot be known with any sufficient degree of certainty and therefore focuses on increasing the degrees of freedom available to an infrastructure organization by widening its system boundaries (see Figure 1). This widening should provide the organization with an increased degree of flexibility to adapt to possible future challenges. Strategic planning is thus not limited to the optimization of local, centralized, long living physical infrastructure providing a single service but rather addresses alternatives beyond these system boundaries. Examples of these alternatives are the decentralization of the infrastructure system (Larsen and Gujer 2001; Wilderer 2004) and the exploitation of synergies with neighboring communities (Hophmayer-Tokich and Khot 2008; OECD 2007) or other infrastructure sectors (OECD 2007). Predominant objective within this perspective is an efficient service provision. This has given rise to a debate on the privatization respectively liberalization of the infrastructure sector, with the argument that only a market-oriented rationale can lead to an efficient resource allocation (Armstrong and Sappington 2006; Martin and Parker 1997).

Although both the modeling and the managerial perspective pursue a defendable strategy to compensate the deficiencies of the adaptive perspective, they both possess three main limitations. First, by confining the scope of alternatives to the incremental development of existing structures, the modeling perspective risks perpetuating the existing path dependencies and thus hinders the arising of innovative approaches, which would profit from wider system boundaries. Additionally, evidence suggests that the gradual enhancement of infrastructure as a response to a changing environment also bears its limits, especially in fast growing economies like China (Huang et al. 2007). On the other hand, increasing the degrees of freedom, as proposed by the managerial perspective also comes at a price. A flexible system bears costs (e.g. idle capacity reserves) that have to be carefully weighted against the potential benefits. Additionally, the increasing complexity leads to a reduced knowledge of the variables relevant for the system and the consequences of ones own actions. Second, both perspectives address and weight objectives in an implicit way. This hampers the evaluation of radically different options. Other than established solutions, these often involve a wide range of (often uncertain) social and political relevant side effects. Cost-benefit analyses are often at pains taking these complexities adequately into account. Therefore an explicit assessment of the valuation criteria are called for (Gezelius and Refsgaard 2007). Third and finally, elaborate future predictions can convey a deceiving sense of security. When characterizing future uncertainty, the modeling perspective parts from the assumption that all relevant external developments and interactions can be identified, quantified and modeled over a time frame of decades. The applicability of this assumption is limited by the complexity and dynamic of the external environment of an organization, which over a period of decades can be quite considerable. Dominguez and Gujer (2006) show in an empirical example from the wastewater sector that the range of unforeseen changes in the context conditions can reach far beyond the range that could reasonably be expected in the context of the adaptive model.

One possibility to overcome these limitations would be to integrate both perspectives when conducting a strategic planning process. In other words, combine an improved characterization of future developments with an extension of the conventional system boundaries. This linking would require a better understanding of the processes and interactions within the new system boundaries in order to assess the impact of external developments. Several quantitative planning models have been introduced recently aiming at this increased understanding (Chung et al. 2008; Achleitner et al. 2007; Benedetti et al. 2008; Panebianco and Pahl-Wostl 2006). Although promising, these models have problems addressing objectives that are not easily quantifiable (e.g. acceptance) and often require important simplifications of the modeled system structures. More importantly, this integration does mostly not lead to a more explicit and balanced consideration of objectives. In fact, concentrating on those objectives that can be quantified can lead to the disregard of important valuation criteria.

In view of the limitations of the three perspectives for handling future uncertainty, we propose to consider an additional perspective that accepts and incorporates uncertainty into strategic planning approaches. This perspective focuses on a discursive elaboration of the future uncertainty faced, the available alternatives and the pursued objectives and builds on foresight respectively scenario planning approaches (see Ringland 2002). Through a series of structured discussions, the spectrum of possible options, objectives and future developments are to be opened for discussion and evaluated under different points of view. The resulting complexity calls for a purely qualitative assessment. Nevertheless, by adopting structured methods, this perspective should help clarify the suitability of different alternatives and their tradeoffs.

The general idea of opening up and discussing the uncertainty spectrum during the strategic planning process is not new and has been successfully applied to several policy and governance contexts (see e.g. Friend and Hickling 2005; Brunner 2005; Glasbergen and Driessen 2005). There is however no experience of the applicability of this perspective for aiding the strategic planning in the infrastructure sector at the municipal level while considering time horizons of decades. Experiences from other fields can not be simply transferred to this context due to its special characteristics such as time ranges of decades, strong technological and organizational path dependencies and the high involvement of local public bodies. Nonetheless, these experiences lead us to expect that this perspective will help open the option spectrum, encourage a balanced consideration of objectives and lead to solutions equipped for dealing with future surprises. Additionally, we expect that the transparence of the decision-making process will increase the acceptance and satisfaction of the decisions reached and foster the understanding of the accepted tradeoffs. Finally, we expect that results from a strategic planning under this perspective can complement the other perspectives.

In the next sections, we will introduce a strategic planning approach for urban water infrastructure sector based on the discursive perspective and illustrate its application and the expected results with the aid of a case study.

3 A strategic planning approach following a discursive perspective

3.1 Requirements for the approach

Based on the above analysis, we derive two requirements for a strategic planning approach based on the discursive perspective.

First, the approach should systematically open up the spectrum of options, objectives and future developments addressed. To do so, we reverse here to foresight respectively scenario planning approaches (Ringland 2002). These are regarded in business literature as adequate for handling future uncertainty in contexts were the relevant time ranges are high and the knowledge of the relevant variables and their interaction is low**.** Although scenario analysis is well known in management and policy literature, it has seldom been applied in the infrastructure sector (see Zegras et al. 2004; Lienert et al. 2006; Truffer et al. 2008; Means et al. 2005 for some exceptions)

Second, the strategic planning approach should encourage a systematic discussion under different points of view about the future challenges, the means available to deal with them and the involved tradeoffs. To be able to include different points of views, the strategic planning process has to be opened for stakeholders outside of the organization such as citizens and industry representatives. The involvement of different stakeholder groups allows to access different forms of evidence and to identify potential conflicts which could eventually lead to a rejection of the strategies chosen (Grimble and Wellard 1997).

3.2 Procedure and Structure

To fulfill the above stated requirements, we propose a strategic planning procedure in which the future uncertainty, the options available and the pursued objectives are systematically discussed in a series of workshops. The process is mainly carried out by a "core group" of four to six decision makers appointed by the infrastructure organization and representing a broad spectrum of points of view and system knowledge. The core group is typically constituted by one or two representatives from the organization, the carrying communes, regulators and a consultant engineering company. The core group carries out the analytical steps and is responsible for elaborating the final recommendations. Furthermore, it has to identify 10-20 additional regional stakeholders that could have an influence or may be affected by decisions taken in the strategic planning process (e.g. citizens and industry representatives). These stakeholders are involved in specific stages of the process, such as the assessment of the future uncertainty faced and the evaluation of the available alternatives.

The process is structured in four modules: Scenario analysis, options analysis, objectives analysis and strategy specification (see Figure 2). The first three modules follow a bottom-up approach in order to achieve consensus among the involved stakeholders regarding the future uncertainties, the available alternatives and the pursued objectives. For example, in the scenario analysis module, prevailing visions or expectations of the future are discussed and decomposed into its core elements like economic development or future legal requirements. In the next step, possible future realizations of the identified elements are addressed (e.g. economic growth or decline). Finally, the different possible realizations are clustered through a systematic approach to plausible future scenarios representing the relevant space of possibilities. These generic steps were repeated in both the options and objectives analysis modules.

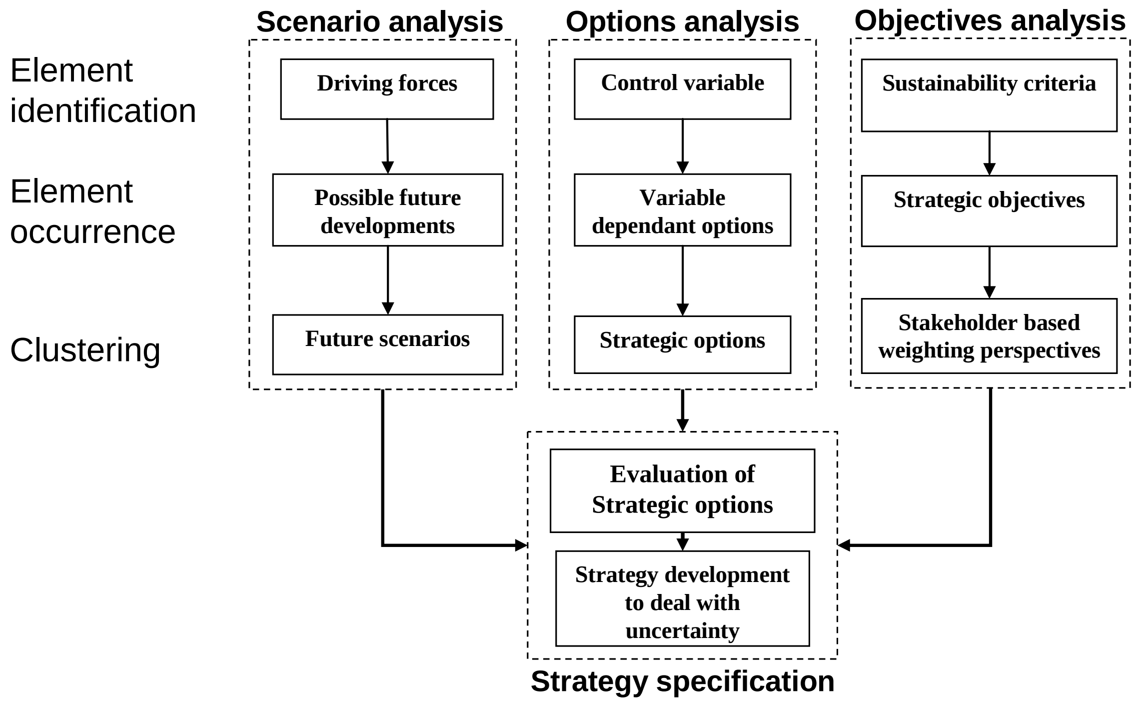

Figure 2 Modules and generic steps of the proposed strategic planning approach. The methodology consists of four modules: Scenario, option and objective analysis and the identification of a strategy. The first three modules follow the same generic steps.

Scenario analysis module Aim of the module is to systematically identify possible, coherent images (so called scenarios) of how the socio-economic context of an infrastructure organization could develop in the future (20-30 years) and the resulting challenges. Here we draw on existing scenario methods as applied for example in the business sector (Ringland 2002; Gausemeier et al. 1998; Schoemaker 1995).

Options analysis module Aim of this module is the identification of a broad range of so called strategic options. These are feasible organizational and technological constellations (e.g. optimization of existing structures, regionalization, etc.) potentially suitable to address the future challenges identified in the previous module. Strategic options are to be understood as a broad informative basis to facilitate a discussion about meaningful alternatives and not as ready to use development alternatives.

Objectives analysis module In this module, the objectives used to evaluate the strategic options are systematically identified, discussed and clarified. As a result a shared set of objectives which have to be considered can be identified and the stakeholders become aware of the scope of different objectives. Furthermore, the specific weights attributed by different interest groups to the individual objectives can be made transparent. Objectives can be related to different sustainability criteria, such as environmental, social, economic or governance objectives. This approach is similar to the one taken by Muga and Mihelcic (2007) to evaluate the sustainability of technologies in the wastewater sector.

Strategy specification module In this module, the objectives, options and future scenarios assessed in the previous modules are related to each other. Specific recommendations for decision makers can be derived from a structured debate about how the strategic options perform under the different future scenarios and how outcomes are evaluated from the points of view of specific interest groups. Strategic options (or elements thereof) can be identified which are accepted by all stakeholder groups and are expected to perform well under a wide range of future scenarios. Additionally, the process helps to specify knowledge gaps, critical future developments and potential conflicts. The first refers to those attributes of the strategic options, which have to be further clarified to allow a decision (e.g. efficiency, feasibility). The second refers to those future developments which have to be monitored due to their potential negative impact on the preferred strategic option. And the third allows to timely identifying potential opponents of a chosen option. Results of these assessments may finally be presented to the actual decision making bodies, which are then responsible to implement the proposed strategy.

The proposed strategic planning approach should lead to solutions based on a careful and balanced consideration of objectives, possible future developments and a wide range of alternatives. Additionally, the process should increase the awareness among the involved stakeholders for existing tradeoffs and different points of view. We will next illustrate with the aid of a case study in a Swiss wastewater organization the detailed application of the proposed strategic planning approach and to what degree these expectations are met.

4 Illustrative Case Study

The case study was part of a Swiss research project aiming at developing a strategic planning approach suitable for publicly owned infrastructure organizations.

The approach was applied in three typical examples of the Swiss wastewater sector, namely Dübendorf, Kloten-Opfikon and Bern. All three case studies are located in an urban environment and have a representative size for wastewater utilities in Switzerland. During the strategic planning process, the authors of this paper participated as facilitators and thus observed the process firsthand. Our role as researchers was to instill methodological rigor in the different steps of the planning process and provide an outside view.

The case study Dübendorf is especially suitable for illustrating the application of the proposed strategic planning approach and how it can complement approaches following other perspectives. The analyzed organization was confronted with the highest degree of future uncertainty and the process required an extensive stakeholder involvement. A comparative evaluation and analysis of the results of the different case studies can be seen in Dominguez et al. (2009)

4.1 System description: Wastewater treatment organization Dübendorf

The wastewater treatment organization Dübendorf operates a 60’000 person equivalent wastewater treatment plant treating the wastewater of three communities in the urban agglomeration of the city of Zurich, Switzerland. The influence sphere of the organization is currently limited to the treatment plant as the sewer system is owned and operated by the individual communities. The treatment plant is running close to its capacity limits and will reach its design age in the next 10 years, which makes planning efforts imminent. Additionally, the receiving water body is highly polluted, as it flows through a densely populated area and receives the treated wastewater from six wastewater treatment plants.

Initial strategic planning efforts by the organization aimed at an upgrade of the existing treatment plant. However, it soon became clear that important uncertainties rendered this approach inadequate. For example, it was unclear if the existing trend of population and workplace growth in the region would continue during the next 20 years or if this trend could reverse. Similarly, the communes served possess important land reserves, which if urbanized would double the population of the region and require important investments into the wastewater infrastructure. On the other hand, there is a high uncertainty regarding future legal requirements in wastewater treatment. E.g., it is unclear if the population in the region will continue to accept the high pollution of the receiving water or if new legal requirements demanding a revitalization of the river could come into force within the next 20 years. In addition, an upgrade of the treatment plant is expected to be extremely costly due to space limitations in its current location.

The proposed strategic planning approach was applied within this context with the aim of identifying an adequate strategy to deal with this and other future uncertainties. In ten workshops, spanned over a period of ten months and involving a total of 16 stakeholders, future scenarios were developed and the available strategic options were evaluated. The results of each module will be presented next.

4.2 Development of future scenarios

In the case study Dübendorf, three scenarios for the year 2030 were developed based on five external factors. These factors represented forces with an impact on the service provided but whose future development can be regarded as uncertain. These driving forces were selected by the involved stakeholders from a wide spectrum of possible driving forces, ranging from job market development to climate change. This spectrum was identified by the core team based on an analysis of the current situation and literature research and enhanced by the stakeholders from the expanded sphere. Figure 3 shows the selected driving forces and their possible future developments over the next 20 to 30 years.

The developed scenarios focused on A) economic downturn, B) increasing quality of life and C) a booming regional economy. They read as follows:

Scenario A: Downturn. The core of scenario A is a negative economic development in the catchment area of the wastewater treatment organization. This development leads to a reduction of the workplaces in the catchment area and to a slight population decrease and consequently to a reduction of the wastewater load to be treated. The personal and financial resources of the communities responsible for wastewater treatment are very limited. As a consequence, water protection activities are reduced to the minimal fulfillment of the legal requirements.

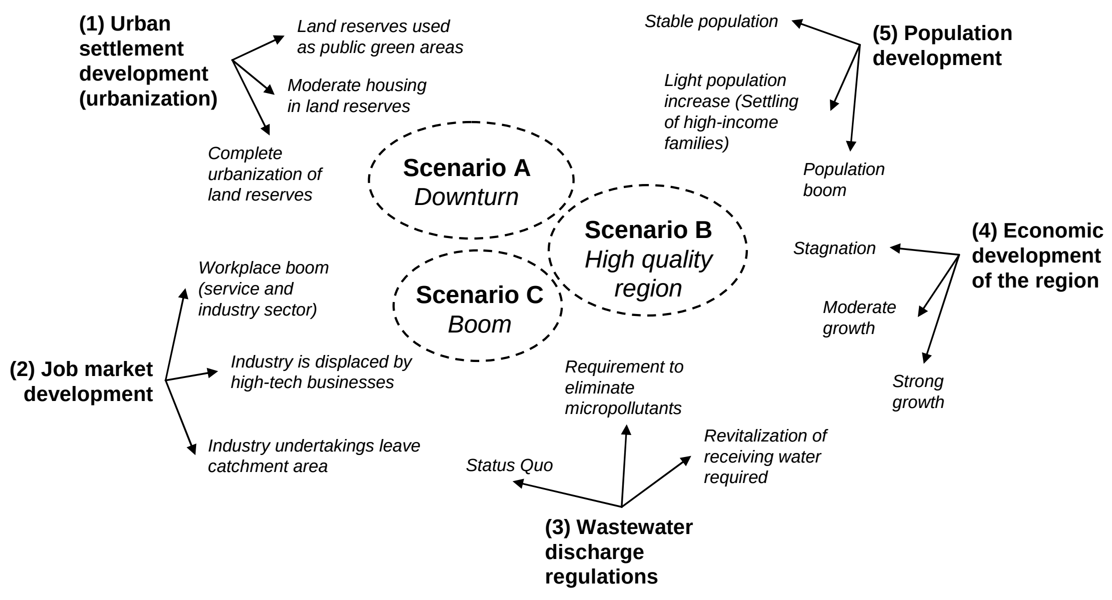

Figure 3 Driving forces in the development of the future scenarios, *possible developments* for the year 2030 and the resulting future scenarios.

Scenario B: High quality region. Scenario B is characterized by an increase in the quality of life in the region. The communities responsible for the wastewater treatment develop to an attractive recreation and housing region. This leads to a moderate increase of the population and thus of the wastewater load to be treated. The number of industry enterprises remains stable, as further growth would be inconsistent with the high quality of life. The expectations regarding the quality of wastewater treatment service are high. An increased ecological awareness leads to the introduction of rivershed management regulations and a revitalization of the receiving water is required.

Scenario C: Boom. The basis of scenario C is the presumption of strong economic growth in the Zurich city region. Due to rapid urbanization the number of people working in the region practically doubles and there is also a strong population growth. Although this development leads to a strong increase of the wastewater load to be treated, the financial resources to manage this challenge are available.

4.3 Assessment of strategic options

The strategic options were created based on four control variables where the organization possessed a configuration leeway: 1) the vertical integration of wastewater related tasks and infrastructure within the catchment area of the existing waste water treatment plant, 2) expanding the fields of activity to new tasks such as the operation of satellite plants, 3) optimization of existing structures (technical and organizational) and 4) the geographical scope of the organization (see Figure 4).

The four resulting strategic options represent the range of potentially feasible and coherent alternatives into which Dübendorf could evolve. This range goes from incrementally developing the current organization to a merging with neighboring organizations:

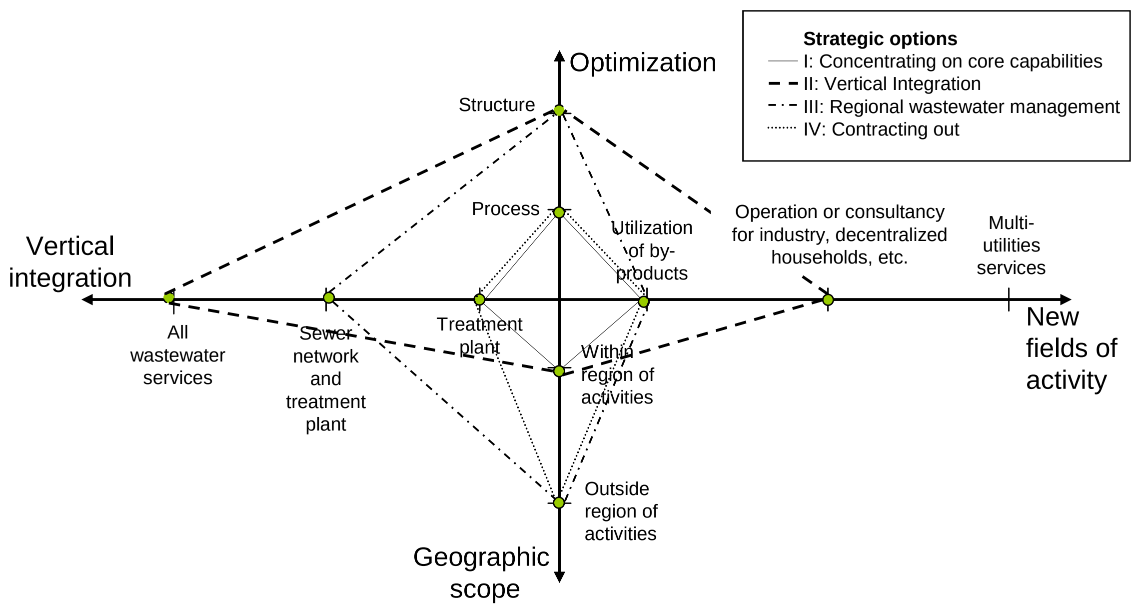

Figure 4 The four strategic options evaluated in the strategic planning process in Dübendorf. They were created based on four control variables where the organization possesses a configuration leeway

Strategic option I: Concentrating on core capabilities. The organization remains in its current state. Future challenges are addressed by optimizing the technical structures as far as possible. Additionally, different activities are undertaken to reduce the incoming load or prevent a further increase. For example, the wastewater of new urban developments within the region is to be directed whenever possible to the treatment plants of neighboring organizations. Conversely, measures are to be taken to ensure a more efficient pre-treatment of wastewater in high-polluting industrial enterprises within the region.

Strategic option II: Vertical integration. The Dübendorf organization is responsible for all wastewater related tasks in the region. These include the ownership and operation of all wastewater related infrastructure and duties such as fee collection and customer consultancy in wastewater related questions. In new urban developments, the use of decentralized systems is to be evaluated and if possible implemented. These systems would be maintained and monitored by the organization. These new responsibilities would require an optimization of the organizational structures, leading to lean decision structures and a higher autonomy from the carrying communities.

Strategic option III: Regional wastewater management. Dübendorf aims at building an organization that integrates all or most of the wastewater treatment plants and sewer networks along the receiving water body. By this, wastewater related problems can be regionally solved, synergies exploited and an integral water protection can be provided.

Strategic option IV: Contacting out. The organization merges with the local neighbor, which takes over the ownership and the operation of the treatment plant. As the neighboring plant possesses a certain degree of capacity reserves and discharges into a less sensitive water body, it is probable that the Dübendorf treatment plant will be taken out of operation and its wastewater redirected to the neighboring plant. Although this measure would prevent the discharge of treated wastewater into Dübendorf's sensitive water body, it would also reduce the influence that the carrying communities have on the organization. From the point of view of the communities this measure is equal to an outsourcing of the wastewater treatment duty and can therefore be regarded as a structural optimization.

4.4 Identification of strategic objectives and weighting perspectives

Figure 5 shows the different objectives that were to be fulfilled by the strategic options identified in option analysis module. They range from compliance with legal requirements to keeping public control over the organization and address the whole sustainability criteria spectrum. The identification took place in a bottom-up process, that is, workshop participants stated what they regarded as potential objectives of the organization, which were then integrated to the sustainability criteria seen in Figure 5.

These strategic objectives were weighted from the perspective of industry and citizen representatives. The two stakeholder groups represented the most influential stakeholders in the region and for which the highest potential conflict can be expected.

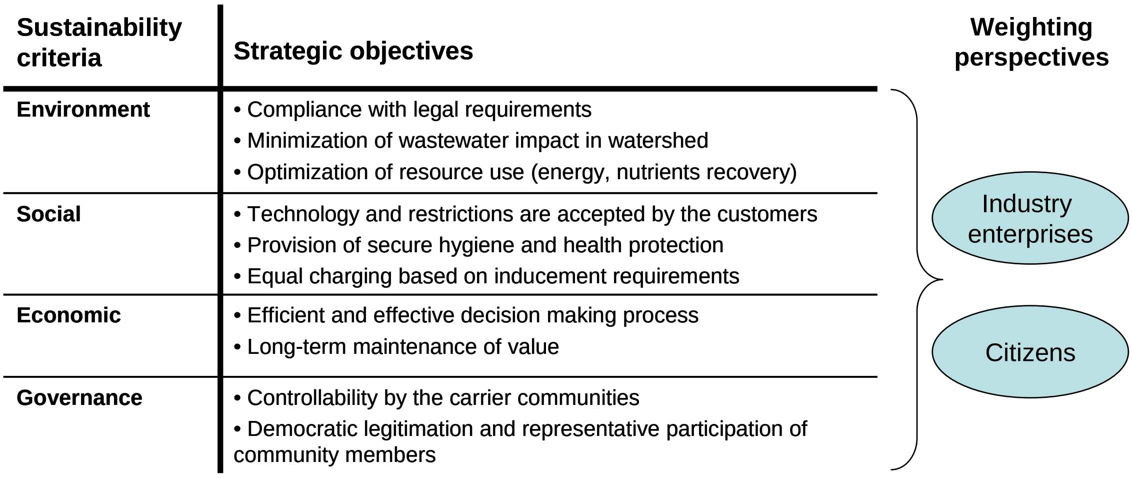

Figure 5 Sustainability criteria and strategic objectives addressed in the case study Dübendorf (aggregated from a more detailed objective tree). Their weighting was performed from the perspective of two stakeholder groups.

4.5 Strategy specification

To specify a strategy for Dübendorf, workshop participants were asked to evaluate the suitability of each strategic option from different stakeholder perspectives and context conditions. To do so, the participants were asked to engage in a role play assuming to be either a future industry representatives or a citizen living under a specific scenario. As such they had to prioritize the different strategic objectives and rank the objectives. This ranking was then used to discuss the strengths, weaknesses and desirability of each strategic option under each of the future scenarios. By this the tradeoffs of each option could be assessed, remaining uncertainties be specified and the timely identification of potential conflicts between stakeholder groups could be derived.

For example, as seen in Table 1**,** the alternative to incrementally adapt the existing structures (Strategic option I) was only regarded as desirable in an economically tense situation (Scenario A) and only by the citizens. In such a scenario both industry and citizens favor low cost solutions and regard environmental objectives as boundary requirements to be fulfilled but not exceeded. The strategic option would imply the lowest degree of investment for the citizens but require industry to upgrade their pre-treatment. As a consequence, the alternative was rejected by the industry.

Table 1 Evaluation of the strategic options (SO) of the case study Dübendorf by the different stakeholder groups under the different future scenarios. Both the desirability of an option as its potential conflicts can be identified from the table.

		Sc A	Sc B	Sc C	Evaluation
SO I	Citizens Industry	++ ---	- --	- --	Undesired and with a high conflict potential .
SO II	Citizens Industry	++ ++	+++ ++	++ ++	High desirability, low conflict.
SO III	Citizens Industry	- -	+++ ++	+ +	Little interest in regional solution as long as it is not externally required. Fear of reduction of co-determination by the carrying communities.
SO IV	Citizens Industry	- ++	(+++) (+)	(+) (+)	Option only desirable if operation of the treatment plant Dübendorf stops. This is however at the moment highly uncertain.

The evaluation led to favoring the option were all wastewater services were integrated (Strategic option II), as it is assumed to possess the highest desirability and generate the least conflict between industry and citizens. Interestingly, it became clear that strategic options that required a reduction in the autonomy of the communities (e.g. strategic option III) were seen as problematic by the citizens despite potential financial savings and environmental benefits. Additionally, the evaluation pointed out important uncertainties that need to be considered in the future. E.g., the option to outsource the wastewater streams could not be discussed in detail, as information was lacking regarding the extent and feasibility of the measure.

Based on this assessment, the strategic option II was complemented and defined in more detail by the members of the core team. This process resulted in a series of recommendations for the organization.

First, it is recommended that Dübendorf instigates a political and organizational process aiming at transferring the responsibility for several wastewater related tasks from the communes to the wastewater infrastructure organization. These include the coordination of duties related to sewer development, maintenance and domestic connections. Additionally, the organization will consult industry in wastewater related matters, a need which was clearly identified by industry representatives in the workshops. Consultancy services, combined with an improved coordination of the wastewater duties and an optimization of the charge fees structures are expected to lead to a decreasing pollutant load. In parallel, a change of the organization structure from an association of convenience to a publicly owned stock corporation is to be induced. Second, the discussion on how the existing land reserves in the communes are to be used is to be monitored. Third, the introduction of a series of complementary measures is recommended if signs indicate that an urbanization of these land reserves will take place in the next years. These include expanding the range of responsibilities to include the ownership of the sewer system and the supervision of the pre-treatment plants in industry. Additionally, the redirection of wastewater streams to treatment plants in neighboring regions and the operation of decentralized plants in the newly urbanized regions are to be considered.

As illustrated by Table 1, a strategy specified under a discursive perspective is the product of an intensive debate about different alternatives, evaluation contexts and points of view among relevant decision makers and/or stakeholders. The scope of the assessed alternatives is thereby not limited to incrementally adapting existing structures but includes alternatives which are usually not addressed under an adaptive or modeling perspective to strategic planning. The structured debate helped to evaluate these alternatives and led to the specification of a strategy that differed strongly from the previously favored simple adaptation of the existing structures. The process also led to the identification of new options. In Dübendorf for example, industry representatives stated the desire to be advised by the organization on wastewater related issues. This option had not been previously considered by Dübendorf, despite the fact that it could have reduced the incoming load to the plant and thus created capacity reserves and delay upgrading measures.

Evidence suggests that the proposed strategic planning approach also increases the awareness of the involved stakeholders for existing tradeoffs and different points of view. For example, the regulators in the Dübendorf core group became aware that despite its environmental and financial advantages, a regionalized wastewater organization could only be enforced if legal requirements obliged the carrying communities to do so. Without a legal compulsion, the alternative will not find enough support among citizens and industry, because the political autonomy of the communities was weighted higher than potential environmental and financial benefits. This weighting also partly explains the poor score of the outsourcing option.

5 Discussion and Conclusion

In this paper we introduced different perspectives to strategic planning in infrastructure sectors and identified their limitations regarding the handling of future uncertainty, the range of alternatives assessed and the consideration of objectives. We argued that a discursive approach to strategic planning could help to overcome these limitations and illustrated this with the aid of a case study. First the reached solutions are based on a balanced consideration of objectives and address both possible future surprises and alternatives beyond the prevailing socio-technical paradigm. Second, a process based on a transparent discussion creates awareness for existing tradeoffs and different points of view. Next, we will discuss the contribution of a discursive perspective to strategic planning in the urban water sector and conclude with some remarks about the future role of strategic planning in infrastructure sectors.

We regard the discursive perspective introduced in this paper as a contribution to a more integrated way to do strategic planning in the urban water sector. The discursive perspective offers an additional approach focusing on a structured, qualitative discussion of the scope of available alternatives, pursued objectives and future uncertainties. That is, strategies developed under a discursive perspective will not be as rich in detail as those developed under other perspectives, but they will have systematically addressed a broader spectrum of possible future developments, available alternatives and valuation criteria. For example, the alternatives assessed under a discursive perspective in the case study envelop a broad range of general directions into which the utility organization could develop in the future. This range encompasses a broadening of the traditional system boundaries and is therefore not limited to incrementally adapting existing organizational and technical structures. By contrast, from strategic planning approaches following an adaptive or modeling perspective we would expect feasible solutions with a clear cost-benefit ratio under defined boundary conditions. These solutions, although detailed, would be limited to end of pipe alternatives focusing on an optimization of the existing structures., such as different technologies for the biological treatment of the wastewater in the central wastewater treatment plant or optimizations of the decision making process.

A discursive perspective to strategic planning is therefore especially suited for framing purposes and the identification of potential conflicts and knowledge gaps related to the strategic options. It is therefore not a substitute for the adaptive, modeling and managerial perspectives to strategic planning but rather a complement. The adaptive, modeling and managerial perspectives possess qualities and strengths that are needed at different stages of the strategic planning process. The final seizing of a wastewater treatment plant requires e.g. quantitative information on the both the expected costs and future load. This information can not be provided by strategic planning approaches following a discursive perspective but rather by approaches following an adaptive or a modeling perspective. However, these stages can profit from a preliminary, framing stage were the scope of the future uncertainty and the available alternatives is openly discussed. In this sense, a discursive perspective supports the modeling perspective by considering a wide range of potential future context conditions on which modeling efforts could build. Similarly, the managerial perspective profits from the explicit consideration of future uncertainties and objectives. Finally, a discursive perspective complements the adaptive perspective by performing a preliminary assessment of the relevant alternatives, which can subsequently be quantitatively evaluated in regard as to their feasibility and costs.

In our opinion, the quality of strategic planning in the urban water infrastructure sector can therefore only be improved through a more balanced consideration of the different perspectives. This applies especially in contexts oriented at more sustainable solutions for infrastructure services. We should therefore move away from isolated perspectives and rather attempt to integrate them into a whole. A perspective to strategic planning based on a structured debate of the alternatives, objectives and possible future developments affecting an infrastructure organization is therefore an important contribution to strategic planning in the infrastructure sector. We argue that this contribution, together with a more balanced consideration of the adaptive, the modeling and the managerial perspective will in the long run improve the quality of strategic planning in this sector. Through this, infrastructure organizations facing uncertainty should be in a better position to identify the capabilities required to secure a long term provision of services. This conclusion should be transferrable to other utility sectors with dominant public organizational forms and capital intensive structures with a clear defined task.

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Chapter 2

Closing the Capability Gap: Strategic Planning for the infrastructure sector

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Closing the Capability Gap: Strategic Planning for the infrastructure sector

Damian Dominguez[1,], Hagen Worch[2], Jochen Markard[2], Bernhard Truffer[2], Willi Gujer[1]*
*Corresponding author
[1] Engineering Department, Swiss Federal Institute of Aquatic Science and Technology, Eawag, 8600 Dübendorf, Switzerland and Institute of Environmental Engineering, ETH Zurich, 8093 Zurich, Switzerland (damian.dominguez@eawag.ch; gujer@eawag.ch)
[2] CIRUS Department, Swiss Federal Institute of Aquatic Science and Technology, Eawag, 8600 Dübendorf, Switzerland (hagen.worch@eawag.ch; jochen.markard@eawag.ch; bernhard.truffer@eawag.ch)

Abstract:
In order to cope with arising challenges in infrastructure sectors, utility organizations have to build up new strategic, organizational and technological capabilities. In the public debate, however, public utility service providers have often been seen as lacking the capacity to identify and/or implement the needed transformation processes. Instead, privatization has been proposed as a panacea to remedy this deficit. Experiences with utility reforms over the past decade have shown, however, that privatization projects are often not realized because they encounter strong political opposition. In this paper, we present results of strategic planning projects in three public wastewater organizations in Switzerland. Based on these experiences, we argue that if appropriate processes are implemented, public utility organizations are able to overcome their limitations in identifying the relevant capability deficits and select adequate strategies to compensate for the deficits. These strategies may deviate substantially across utilities due to differences in the goals pursued. We conclude that a widespread adoption of strategic planning methods by public utilities tends to close the capability gap, thus representing a viable alternative to privatization.

Keywords: Infrastructure, utility organization, privatization, strategic planning, capabilities, scenario analysis, foresight, waste water

1 Introduction

Several recent studies on the future of infrastructure sectors have revealed that there is a consistently widening gap between the requirements for ensuring the delivery of utility services and the capacity of the public sector to meet those requirements (OECD 2006; 2007; Urban Land Institute and Ernst & Young 2007; UNESCO / World Water Assessment Programme 2003; 2006). Public utility companies have often neglected to acquire and build up adequate capabilities including advanced managerial decision tools for long-term investment planning, financial and operational controlling systems, know how in demand management or competences on regulatory issues and new technologies. This capability gap is accentuated by emerging challenges such as increasing uncertainties in socio-technical context conditions, massively expanded investment needs, shifting objectives, market liberalization and changing regulations. Rapid urbanization and a general trend among public administrations of paying little attention to the often alarming state of the infrastructure systems make this gap even more critical in many parts of the world (UN-HABITAT 2006). Partly as a consequence, an intensive political debate has fundamentally questioned the prevalent goals of utility and infrastructure network management (see Hirsh 1999; Gray 1998). For almost hundred years the provision of ubiquitous, reliable and affordable services was the primary objective of utility managers and local officials. Since the early 1990ies, economic efficiency has gained predominance in the public discourses.

The capacity of public utility organizations to close this capability gap has often been considered as limited. At the organizational level, utility organizations have to address a variety of economical, environmental and social objectives, the weighting of these objectives varying from organization to organization. However, decision makers in public utilities are often unclear about how to weigh the relevance of the different objectives and the related tradeoffs, which complicates the identification and acquisition of adequate capabilities. Finally, public utility organizations tend to assess a restricted range of options. This is due to the fact that many publicly owned utilities have been reluctant to build up strong management teams. Strategic decision making is therefore often delegated to consultant engineers. This division of labor may imply an agency problem (Grossman and Hart 1986; Eisenhardt 1989) that risks favoring the perpetuation of established technological and organizational paradigms, and thus restricts the option ranges considered.

As a countermeasure to the widening capability gap, fundamental sector reform initiatives aiming at privatization and liberalization have been proposed worldwide (Andrieu 2007). The argument is that a purely private business rationale can guarantee the investment in core capabilities. However, over the past few years attempts to privatize utilities have also provoked strong political opposition in many parts of the world and are therefore not always a viable alternative. Besides political impediments, also private companies have sometimes been reluctant to engage in utility sectors. Profitable private investment in the infrastructure sector depends crucially on the ability of a country to provide a stable and credible institutional environment for investors (see Henisz 2002).

In this paper, we argue that privatization is not a necessary precondition for addressing the capability gap. Public utilities can identify the capabilities to deal with the changing conditions by applying adequate management processes and adopting them to their specific circumstances. We particularly argue that by implementing appropriate formal strategic planning processes, public utility organizations should be able to overcome their limitations in identifying the capability deficits and select adequate strategies that not only compensate for these deficits but also effectively account for the specific objectives of each organization.

To support this argument, we present results of three case studies of strategic planning efforts in publicly owned and managed infrastructure organizations in the Swiss wastewater sector. From the case study evidence, we derive two main insights. First, we find that appropriate forms of strategic planning support the identification and development of needed capabilities in public utilities. From this result, we conclude that the capability gap tends to become less and less pronounced if the management of public utilities implements adequate strategic planning processes. Second, the thereby identified strategies may still vary substantially across utilities due to differences in the objectives pursued. Consequently, a widespread adoption of strategic planning methods by public utilities tends to close the capability gap but results in an increasing heterogeneity of organizational forms within the sector. Thus, the variation in organizational forms is likely to remain substantial for a considerable time in the future.

The remainder of the paper proceeds as follows. In the next section, we specify the requirements of strategic planning for publicly run utilities. Based on this analysis, we propose a foresight based strategic planning approach suited to address the specific uncertainties and heterogeneous value considerations in infrastructure sectors. The next section briefly introduces the sectoral context of our case studies, namely the water-related utility sector, which has traditionally a high public sensitivity. Then, we present the results of the application of the strategic planning approach to three wastewater organizations in Switzerland. Finally, we discuss the results of the case studies and draw some general conclusions for closing the capability deficits in infrastructure sectors.

2 Specificities of strategic planning in infrastructure sectors

Strategic planning is a set of processes used by organizations for the purposes of gaining a better view of the future, reaching a common understanding among different parties about how the organization should proceed, and aligning different interests toward a shared goal (see e.g. Grant 2003; Klayman and Schoemaker 1993; Schoemaker 1992; Schoemaker 1993). Strategic planning is a well established management domain and a variety of methods have been developed over the past decades to enable managerial decision making under uncertainty and complexity (cf. Whittington 2006; Whittington et al. 2006; Schoemaker 1995). Their aim is to overcome characteristic human cognitive biases such as overconfidence and to provide a basis for the decision making process by structuring complex and interdependent future developments into discrete and coherent states (e.g., Barnes JR. 1984; Schwenk 1984; Schoemaker 1993).

Traditionally, strategic planning has received rather little attention in infrastructure sectors. On the one hand, there was no vital need for sophisticated strategy making. Competition was low or not existing. Socio-economic context conditions remained within certain bounds and investment risks were borne by captive customers or the general public. On the other hand, there has been in general an insufficient concern in the organization studies literature on how to improve the performance of public organizations (Kelman 2007). However, awareness for the need of adequate strategic planning methods has been increasing in the field of infrastructure based services and various planning methods to inform strategy making have recently received attention (Dyner and Larsen 2001). These include for example modeling tools, (e.g. Dyner 2000) real option approaches (e.g. Gil 2007), decision analysis tools (e.g. Cherni et al. 2007, Heinrich et al. 2007) and the assessment of capabilities as a complement to conventional SWOT analysis (e.g. Panda and Ramanathan 1997).

In general, strategic planning approaches in the infrastructure sector may be attributed to one of three perspectives, namely the adaptive, modeling and managerial perspective (Dominguez et al. Submitted). The adaptive perspective to strategic planning represents the currently dominant approach in the engineering practice. It relies upon linear models providing forecasts on the base of past developments and current trends. Once a strategic plan is implemented, unforeseen changes in the socio-technical context are often addressed by incrementally adapting the infrastructure system (for an example in the wastewater utility sector see Dominguez and Gujer 2006). In contrast, the modeling perspective focuses on an improved characterization of the future states of the system. It aims at predicting these states by using modeling approaches that specifically address the uncertainty issue. Finally, the managerial perspective assumes that uncertainties are too large to be known with any degree of precision. It therefore focuses on improving the flexibility of the infrastructure organization by implementing specific organizational processes and technological features.

Except for the adaptive perspective, the other two approaches on strategic planning are little established in the infrastructure sectors. All three perspectives also exhibit a series of limitations as they predominantly come forward with only a small set of alternatives, a deterministic view of the future and an implicit consideration of objectives and tradeoffs (Dominguez et al. Submitted). This hinders the emergence of a broad agreement among the different stakeholders groups and an adequate handling of future uncertainty.

A strategic planning approach suitable for the infrastructure sector should explicitly consider its particularities such as high capital needs, long relevant time frames, path dependencies and the multiple objectives imposed onto service provision. First, the relevant time frames in the utility sector lay in the order of magnitude of decades (Lienert et al. 2006). Infrastructure sectors such as water supply, sanitation, electricity supply and telecommunication are characterized by a sizeable, capital intensive physical infrastructure (e.g., widespread networks, large plants) that is built to be operated over decades to amortize the high initial investments (Markard and Truffer 2006). Making strategic decisions in the light of several decades of recovering investment cost entails a high degree of future uncertainty. For example, new political priorities may lead to stricter environmental regulations, and therefore increase the costs or even put established technologies at stake. Uncertainty may also derive from changes in the market conditions as in the case of telecommunication, electricity and gas supply due to market liberalization.

Second, infrastructure sectors are characterized by a high degree of interdependency typical for large technical systems (Hughes 1987; Joerges 1998). Network operations and service provision are tightly linked to established and well adapted technologies as well as to organizational and institutional structures Markard and Truffer 2006). What follows is a pronounced reluctance to undergo technological, organizational or institutional change which leads to considerable path-dependencies.

Third, utility organizations provide basic services that are of key relevance for the functioning of almost all other fields of socio-economic activity. Adequate service provision is often even critical for human well-being and the quality of life. For that reason, the objectives imposed on infrastructure services are typically multi-dimensional. Services, for example, have to be reliable, available at any time and affordable for the society and economy at large. A further objective dimension is the limitation of environmental impacts. This is particularly pronounced in sectors such as energy supply and wastewater treatment, which bear risks for substantial environmental pollution if the infrastructure is inaccurately operated and managed. Against this background, policy intervention and regulation always played a central role in infrastructure sectors and continue to do so despite the recent trend towards liberalization and privatization (Héritier 2001). Traditionally, public bodies have been directly involved in service provision and sectors such as water supply and sanitation are in many countries still dominated by public utility companies (cf. Aubin and Varone 2007; Pinsent Masons 2007).

In summary, we may conclude that strategic planning in infrastructure sectors is typically characterized by high resource commitments, a considerable degree of future uncertainty, and multiple objectives. While this holds true at a general level, strategic planning approaches suitable for utility organizations should also address the particularities of each infrastructure sector and each organization.

At the sector level, the context of strategic decision making depends for example on the competitiveness of the business environment, the technological innovation rate and the specific regulatory environment. At the organization level, strategic decision making is influenced by local context conditions such as the degree of direct political influence. For example, constrains can occur as a consequence of the level of control that the municipalities establish for their utilities. Very roughly, we can differentiate between two types of situations. At the one end of the spectrum are municipalities that set the provision of cost-efficient services high on the agenda and tend to be more willing to delegate decision making responsibilities to the utilities' management. At the other end are municipalities that favor direct control and social objectives, and as a consequence avoid sharing power and transferring responsibilities. Consequently, the perceived strategic options may differ largely in the two situations depending on the objectives the decision makers pursue. In the first situation, for example, utility companies tend to be free to enter into a new business field, reorganize their organizational structure and take over other service providers. These options may not be available for organizations at the other end of the spectrum**.**

3 A strategic planning approach suitable for public utilities

In decision situations, in which multiple objectives have to be balanced against each other, strategic planning should be carried out in a way as to explicitly and transparently deal with different value positions. In general, the strength of strategy development procedures is not only to come up with adequate decisions but also to derive a common problem understanding among the involved participants (Godet and Roubelat 1996). In situations in which stakeholders differ regarding their objectives, strategic planning can benefit from a participatory approach. Participation may be thereby oriented at those groups or representatives that have a direct or indirect influence on the strategic development of the utility company. Participation can be limited to certain steps of the strategic planning process.

Formal strategic planning typically encompasses a series of generic steps including the explication of strategic objectives, the analysis of the business environment and available resources, the development of strategic options and their evaluation, and an implementation plan (Schwarzenbach et al. 2006). We structured our approach similarly but adapted it to meet the above mentioned requirements. In the following we propose and sketch a strategic planning approach consisting of four steps. An implementation plan is however not included because its development represents a long-term project in each utility, which would be beyond the scope of this research project.

The first step of our approach is a systematic assessment of the multiple objectives imposed on the utility company and their prioritization. This lays the basis for the evaluation of the available strategic options and the identification of challenges that can result from developments in the organizations' context. Examples of pursued objectives are equal and secure service provision for the population, effective and efficient use of resources, cost recovery, environmental protection and political control over the infrastructure assets.

As second step, a scenario analysis explicitly addresses context uncertainty inherent in the strategic decisions at hand. Under circumstances of high uncertainty, explorative and mostly qualitative scenario techniques with a focus on the influence of external factors are an appropriate tool to inform strategic planning at the corporate level (e.g. Borjeson et al. 2006, Dyner and Larsen 2001; Godet and Roubelat 1996). Here we draw on existing scenario methods as applied for example at the corporate level or in broader foresight approaches (e.g. Ringland 2002 or Gausemeier et al. 1998). Such methods are based on coherent scenarios for long time horizons. The idea is to sketch out a range of possible future states defined by a limited number of key context factors. These forces determine the future socio-technical context in which the organization has to operate. The actual future outcome may then lay somewhere along the continuum bounded by that range (Courtney et al. 1997). Each of the so identified coherent future states defines a scenario. In our approach, scenarios of the socio-technical context of the utility company are developed and the challenges arising from these scenarios are discussed.

The third step is the development of strategic options. The key issue for strategy making at the corporate level is to (re)define the core business field(s) of the company and target markets (Grant 2003). For utilities, this typically includes a reconsideration of the existing business model, e.g. in terms of vertical integration or disintegration but also to enter into new fields of activity (diversification) or to expand into new regions. Similarly, a strategic decision may be to exit a particular market or region. In the case of utility companies, however, the range of options is often limited due to the above mentioned constraints. For example, vertical integration may be in conflict with regulations on the ownership of the infrastructure network, geographical expansion may be impossible due to regionally defined monopolies, and mergers may be prohibited by public ownership. Moreover, changes in the company's organizational structure to adapt to the new strategy may also be difficult to implement if a specific organizational form does not get the support from all public authorities with a stake in the utility.

In our approach, we therefore explicitly address four strategic decision making dimensions, namely the level of vertical integration, entry into new business fields, the geographic scale of operation, and the optimization of organizational processes and structures. Along each of the four dimensions, pre-defined options are discussed and evaluated with regard to their case specific feasibility. These dimensions provide a framework to guide the strategic planning process. They can be further specified (or new dimensions can be added) in the course of the process to include issues such as personnel management, asset management, the bureaucratic structures and both the regulatory and supplier relationships. An overview of different issues that a utility organization can specify can be derived from MacGillivray et al. (2006).

The fourth step of the approach evaluates the feasible options regarding their suitability to meet the objectives of the organization. Based on the results from the first step, the objectives are considered according to the stakeholders' prioritization. In addition, the evaluation is undertaken for each future scenario, as the suitability of an option to meet the objectives is dependent on the socio-technical context conditions. Given the results from the different scenarios, the most adequate strategy is chosen and further developed. The strategy defines the options to be primarily followed and identifies the relevant context developments that the utility has to monitor.

Applying this strategic planning approach in public utilities, all four elements should be addressed discursively and reflected in a series of workshops with the management team, possibly involving relevant stakeholders. The selection of participants to these processes is case dependent and not necessarily limited to members of the organization. For example, relevant decision makers for public utilities are often distributed over several public bodies. Citizens and industry representatives can have a high influence on the strategic orientation of public utilities and may therefore have to be included in the process.

The strategic planning approach proposed should not only lead to the identification of a carefully considered strategy but also stimulate learning processes within the organization. By the involvement of different stakeholders we expect to increase the acceptance of the resulting strategy among the relevant decision makers in the municipalities, and create awareness and a better understanding of the complexity and uncertainties surrounding utility systems. Based on the dynamic capabilities literature (see. e.g. Teece et al. 1997; Zollo and Winter 2002), we expect that this learning effect will provide the management team with the capability to deal more reflexively with the increasing challenges that the utilities face.

4 The case of water-related infrastructure

The proposed approach was applied and tested in the Swiss wastewater infrastructure sector, as the water-related infrastructure and the wastewater sector in particular show typical properties of socio-political contexts critical toward privatizations. As many other infrastructure sectors, it exhibits a high reluctance to undergo technological and organizational change. With few exceptions, publicly owned utilities providing water supply and sanitation services at the municipal level are the dominant organizational form in most countries (cf. Aubin and Varone 2007; Pinsent Masons 2007).

Worldwide the public sector plays a decisive role in providing water-related infrastructure services. Water supply and sewerage are mostly operated by public sector organizations in the 30 OECD countries, Brazil, China, India, Indonesia and the Russian Federation (Pinsent Masons 2007). By contrast, the percentage of the population served by private sector companies is rarely higher than 50%. This percentage applies to water supply in the United Kingdom, France and the Czech Republic and for sewerage services in these three countries and Spain. In most of the remaining countries, including the United States, Canada, New Zealand, Japan, China, India, Indonesia, Mexico, the Netherlands, Germany and Switzerland, the percentage of private provision for both water supply and sewerage services is significantly below 20% (Pinsent Masons 2007).

If we concentrate on the wastewater infrastructure sector, we observe that besides the dominance of public forms, wastewater service provision is commonly highly localized and often a municipal function. The wastewater infrastructure system consists of central treatment plants and a capital intensive sewer network. The latter transports the wastewater from households and industry to the treatment plant. However, industrial wastewater is often (pre) treated on site by its producers. Municipalities and regional districts play a dominant role regarding asset ownership, payment of investments, definition of the service, and price setting (Palaniappan et al. 2007). Thus, wastewater services are mostly provided at a municipal or regional level. For example, the US sanitation sector consists of about 16,000 wastewater treatment systems serving around 85'000 political entities. Similar structures can be observed in many European countries (Finger et al. 2007; Luis-Manso 2004). Often there are also different municipal organizations owning, operating and maintaining the wastewater treatment plants and the corresponding network systems.

The Swiss wastewater infrastructure sector can be regarded as a representative example of utility sectors with highly localized structures, dominant public organizational forms and high public sensitivity. There are about 700 wastewater utilities providing wastewater treatment service for the 7.5 million people living in 2,500 municipalities. In addition, there are 3,300 very small wastewater treatment facilities (see Maurer and Herlyn 2006). The utility organizations are similarly structured. Formally they have a general management and a supervisory board. In some organizational settings, the management is part of the municipal or regional administration. In other cases, the management consists of appointed managers. The general management is responsible for the operation of the utility but has limited discretionary power and budgetary control regarding strategic decisions and investments. The supervisory board is composed of the representatives of the municipalities that own the utility. They define the strategy of the utility and investment volumes according to the decisions of the legislative body of their municipalities. The utilities differ formally as some organizations are partnerships of convenience, in which municipalities are associated to accomplish a specific purpose. Others are private corporations with the participating municipalities being the sole shareholders.

In the following we argue that, regardless of its organizational specificities, public wastewater utilities can remedy their limitations in identifying adequate and feasible options to consciously address future challenges while maintaining their specific objectives. To test this hypothesis, we applied the strategic planning approach introduced above in three case studies in the wastewater infrastructure sector.

5 Case Study: Data and Analysis

5.1 Selection Criteria and Description of the Cases

The proposed strategic planning approach was applied in three representative Swiss wastewater utilities, namely Bern, Kloten-Opfikon and Dübendorf. All three case studies are located in an urban environment. Kloten-Opfikon and Dübendorf are municipalities adjacent to the city of Zurich and Bern is the sole wastewater utility of the city of Berne. They have a representative size for wastewater utilities in Switzerland and provide their services to all customers in their region. During the strategic planning process, the authors of this paper participated as facilitators and thus observed the process firsthand. Our role as researchers was particularly to instill methodological rigor in the different steps of the planning process. We further provided an outside view in assessing the influence of the socio-political environment and identifying the relevant external factors. In this sense, the methodological foundations of our research relates closely to the action research approach (cf. Chisholm and Elden 1993; Eden and Huxham 1996; Lüscher and Lewis 2008).

The analyzed utility organizations were either directly asked to participate in the project or selected based on a public announcement in both professional magazines and the annual meeting of the professional association of sanitation experts in Switzerland. While the former applied for Bern and Kloten-Opfikon, the latter applied for Dübendorf, which was selected out of ten wastewater organizations that expressed their interest to participate.

The selection criterion was representativeness with respect to the different objectives that the utility organizations pursue. The three organizations differ primarily in how they weigh the objectives of wastewater infrastructure services (see Figure 1). Bern primarily focuses on economic objectives such as efficiency and profit generation. Other objectives are mainly perceived as imposed requirements that have to be fulfilled. Kloten-Opfikon favors environmental objectives and economic efficiency. In Dübendorf, the main objective of the municipalities owning the wastewater utility organization is to maintain control over public services. Social, environmental and economic objectives are regarded as requirements that have to be fulfilled but are not the primary focus of the organization's operations. In contrast, the forces driving the future development of the socio-technical context of the utilities are more or less the same and the organizations can by and large draw on the same strategic options to face these developments.

The different focuses of the analyzed utilities can to a considerable extent be traced back to a more general political orientation of the municipalities responsible for the infrastructure. In the case of Bern, different reforms have been and are being implemented at a state level to introduce elements of private management into public service sectors. This partly explains the openness of responsible municipalities in Bern to adopt economic objectives as the primary strategic orientation of the wastewater utility organization. In contrast, the municipalities responsible for Dübendorf have been more and more incorporated into the metropolitan dynamics of Zurich. As a reaction, these communities have attempted to remain independent and maintain a strong local identity, and therefore avoided sharing responsibilities with others. This is prominently expressed in their approach to manage their infrastructure systems. In contrast, Kloten-Opfikon has long lost its identity as an independent municipality. As a consequence, decision making responsibilities are often delegated or shared with other municipalities. In sum, the three cases represent different ways in which public organizations can weigh their objectives.

The difference in how the objectives are weighted is partly reflected in the structures of the organizations and in the influence of its management on strategic planning (see Figure 1). Kloten-Opfikon and Dübendorf are organized as an association of convenience between municipalities. Bern, on the other hand, is organized as a publicly owned stock company.

Regarding the influence on strategic planning, the strategic decisions in Dübendorf are taken by politicians representing the municipalities served by the utility organization. In Bern the management can decide to a high degree independently of the municipalities served. The management of Kloten-Opfikon is not as independent as that of Bern, but it has a high influence on the political bodies governing the organization, and therefore determines strategic decisions to a certain extent.

The different degrees of decision making leeway translate into differences in both the organizational strategies and the identification and remediation of capability gaps. With the exception of Bern, the strategies followed prior to the application of our strategic planning process were geographically highly localized and focused on prevailing technological paradigms. Bern, whose treatment capacity is almost six fold that of Kloten-Opfikon and Dübendorf, aimed at exploiting its managerial and technical capabilities through a growth strategy. Precisely, efforts were taken to gain new customers, integrate the municipal sewer networks and purposefully exploit by-products such as biogas. In contrast, Kloten-Opfikon and Dübendorf had limited their activities to operating one central wastewater treatment plant and optimizing their internal processes. While in Dübendorf this optimization focused mainly on the decision making processes of the organization, in Kloten-Opfikon it was more far-reaching. The organization constantly aimed at improving the quality of its service by exceeding legal environmental requirements through technical optimizations. In addition, various benchmarking processes have been implemented to ensure economic efficiency. Despite these differences, both Kloten-Opfikon and Dübendorf regarded improving the utility’s operation processes as the key strategy to address future challenges. The focus was thereby on technological processes such as increasing the treatment capacity of the plant. Regarding future uncertainty, all organizations addressed possible future challenges in a rather unsystematic way. Particularly Dübendorf and Kloten-Opfikon missed a clear specification of future challenges.

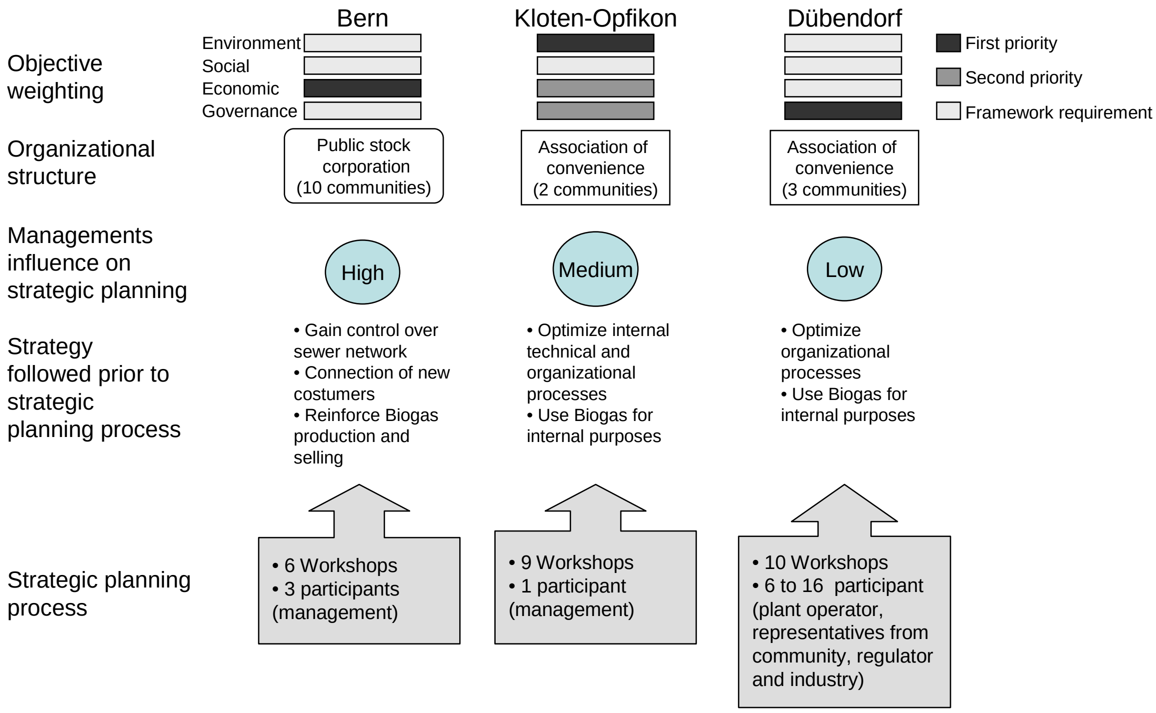

Figure 1 Comparison of the case studies conducted.

Summing up, in all case studies future uncertainty was insufficiently addressed and, with the exception of Bern, the scope of the strategic options followed was rather narrow. It was under these starting conditions that the strategic planning approach was conducted in the organizations

5.2 The Strategic Planning Process

The strategic planning process was conducted in six to ten workshops spanned over a period of four to ten months and involving a varying number of stakeholders (see Figure 1). In Bern and Kloten-Opfikon only the management of the organizations was involved, as it is mainly responsible for decisions on the strategic direction of the utility[1]. The process in Dübendorf, by contrast, involved a broader range of stakeholders. These were selected by a six person committee appointed by the utility organization, which included representatives from the municipality, the utility, a local engineering firm and the regulator. Dübendorf required a higher degree of participation due to the dominant role of public bodies on the strategy development and the small influence of the utility's management on this process. Thus, two workshops out of ten were run with an enlarged stakeholder group involving representatives from political and institutional bodies, citizens and industry. During these workshops, the stakeholders underwent a guided reflection about their objectives, possible future challenges faced by the utility and the different feasible strategic options suitable to meet the former two. Special weight was thereby given to a broad thinking. The workshop participants were especially encouraged to consider options differing strongly from the ones already accounted for in the existing strategy.

The strategic options evaluated were derived from the four strategic decision making dimensions for utilities discussed in chapter 3 (see Table 1 for an overview of the strategic options in the wastewater sector along these dimensions). The dimension "vertical integration" describes strategic options along the value chain that are available for the utilities to act upon. These strategic options range from concentrating on the operation of the treatment plant to managing all wastewater related activities in a region. In addition to operating and maintaining the treatment and sewer network infrastructures, the latter also includes managing the access to the network systems, fee collection and consulting industrial customers. On the other hand, the dimension "new business fields" describes strategic options that increase the horizontal scope of the utilities. Options range from exploiting economically viable by-products such as biogas to using synergies and integrating with related infrastructure sectors such as drinking water, waste disposal and energy production. The dimension "optimization" describes internal strategic options with an impact limited to the organization's own processes and structures. Possible options in the wastewater sector are an incremental optimization of the existing technical and organizational processes or a structural optimization addressing e.g. a corporatization or the set-up of a new business unit for decentralized household technologies. Finally, the "geographic growth" dimension describes the geographical range of the organization. Options such as the connection of new customers to a treatment plant owned by the organization or the provision of the expertise present in the organization to a wider spectrum of customers are considered. For example, experience

[1] The involvement of a reduced number of stakeholders in the strategic planning process may lead to a biased evaluation of both future challenges and alternatives. To avoid this effect, the facilitators of the process conducted a series of interviews with external stakeholders and analyzed available gray literature on regional developments with a potential impact on the utility. The workshop participants were confronted throughout the process with the information that resulted from this analysis. In addition, insights won from the other cases studies were used by the facilitators to recognize and address possible biases.

gained in the operation of sewer networks can also be sold to other municipalities than those owning the utility organization.

Table 1 Options evaluated during the strategic planning process, Moving along the different strategic dimensions requires additional technological and managerial capabilities in the utility organization.

	Strategic options	Option description
Vertical integration	Focus on wastewater treatment plant operation	Operation and long-term value maintenance of central wastewater cleansing facilities.
	Integrated management of municipal wastewater infrastructure (plant and sewer)	Operation, value maintenance and surveillance of the entire wastewater infrastructure, including sewers and wastewater treatment plant.
	Integration of all wastewater related services	Integration of all wastewater related services and activities into one organization, e.g. infrastructure, access to the network system, consulting for customers, surveillance, etc.
New business fields	Valorization of by-products	Valorization of by-products of the waste water treatment process (mainly organic matter). In particular, biogas generation and fertilizer production.
	Operation of communal satellite plants	Utility offers operating services to other municipalities and/or consults other utility operators.
	Operation of non-communal satellite plants	Consulting services and/or operation of wastewater treatment plants outside the communal domain, e.g. industry, decentralized households, highway drainage, etc.
	Establishment of multi-utility services	Integration of related infrastructure services such as drinking water, waste disposal and energy production.
Optimization	Process optimization	Incremental optimization of the company's technical and organizational processes (e.g. additional cleansing step, increasing the treatment capacity, accelerated decision making, expanding the range of advised customers).
	Structure optimization	Reform of the technical and organizational structures of the company, e.g. through technological innovation, outsourcing or corporatization.
Geographic growth	Within region of activities	The organization concentrates its activities to the existing service area.
	Outside region of activities	The organization expands its geographical range of action, e.g. by taking over (ownership) wastewater treatment plants outside the native region or connecting customers that were formerly connected to another treatment plant (expanding regional reach).

Moving along the different strategic dimensions requires additional technological and managerial capabilities in the organization as the level of vertical and horizontal integration increases and the operation of the system becomes more complex. For example, increasing the vertical scope by integrating the operation, surveillance and maintenance of the network infrastructure involves technological and financial capabilities that are not readily available from operating a wastewater treatment plant. In the same sense, a higher level of horizontal integration tends to go along with higher technological and managerial capabilities at the organizational level. For example, an organization would require a substantial increase of its capabilities if it integrated its wastewater infrastructure into other public service sectors with the aim to operate and manage a multi-utility company. An increasing level of required capabilities can also be projected for the growth and optimization dimensions, as the complexity level increases along these dimensions. For example, doubling the capacity of a treatment plant does not require additional expertise. By contrast, establishing a new treatment technology would require expertise currently not present in the organization.

5.3 Strategy Development Results

The broad reflection upon objectives, options and context conditions and the involvement of different stakeholders characterizing the applied strategic planning approach encouraged a series of debates from which different strategies emerged. Key debate in Bern was the risk assessment of their growth strategy. While the management wanted to hold on to the pursued strategy, voices in the directory board argued that the risks involved were still unclear. The confrontation with possible future scenarios not only made it clear how a growth strategy could set the utility organization in a better position to face future challenges. It also pointed out that expanding the scope of the strategy to include the operation and maintenance of satellite plants would be advantageous in several future scenarios. Before the planning process, Bern had only vaguely considered the option to operate satellite plants. As a consequence, the operation of satellite plants was not an integral part of its strategy. In the strategic planning process, Bern recognized that the introduction of more constricting treatment regulations, as described in one future scenario, would technologically and financially overwhelm most small treatment plants in the region. In this context, an offer from Bern to take over the operation of the wastewater infrastructures would probably be readily accepted by the overstrained municipalities. The option to operate and maintain satellite plants would also be advantageous in other future scenarios. For example, in a scenario describing the market entry of international and financially strong wastewater infrastructure operators, this option would increase the asset capital and the decision-making flexibility of the company and therefore increase its opportunities to survive as an independent organization.

The strategic planning process in Dübendorf and Kloten-Opfikon was also accompanied by intensive debates on the suitable alternatives and their long term consequences. In Dübendorf, the discussion circled primarily around two alternatives. To either integrate all wastewater related services into one utility organization or to merge with neighboring wastewater organizations and thus unify the wastewater management of the region. The representatives of the regulatory body participating in the process clearly expressed their preference for the latter, as a positive environmental impact is expected from an increased organizational and technical cross-linking between the different utilities. By contrast, the community representatives favored the alternative to integrate all wastewater related services into one organization. Although at the end of the process all parties acknowledged the positive environmental impact of a regional organization, the incentives to undergo such a transformation were regarded as extremely low by both community and utility representatives. The key debate in Kloten-Opfikon related to the improvement of the organizations flexibility, as both the wastewater load to be treated by the organization and the imposed legal requirements diverged strongly between the future scenarios. Discussion centered on a purely technical solution (increasing the technical capacity of the treatment plant) and, akin to Dübendorf, a more regional alternative. Also subject to discussion were the organizational capabilities required to handle the identified future challenges, which led to a critical analysis of the established decision making structures.

As a result of the strategic planning processes, all organizations identified strategies differing strongly from those followed before the process (see Figure 2). That is, the deliberate consideration of objectives, context conditions and options resulted in the development of more far-reaching strategies. Bern, which prior to the strategic process had already followed a growth strategy, decided to expand its strategy range along the dimension “new business fields” by considering the operation of communal and non-communal satellite plants. Kloten-Opfikon decided to pursue a geographical growth strategy. The strategy aims at integrating several neighboring wastewater treatment organizations and the corresponding sewer networks into one organization that provides wastewater treatment service for a larger region.

By contrast, Dübendorf decided to expand along the dimension “vertical integration”. In addition, advisory activities for industrial customers were included as part of its strategy, whereas prior to the strategic planning process Dübendorf maintained little or no contact with them. However, during the process it became clear that advising the industrial costumers on wastewater related issues would be a key measure for addressing future challenges in all scenarios. Furthermore, the industrial customers communicated that they saw the lack of contact as a problem and explicitly wished to be advised by the organization on wastewater related issues. By integrating all wastewater related services into its organization, Dübendorf goes beyond its prior activity of only operating and maintaining the treatment plant. This implies providing a variety of additional services such as operating the sewer networks, consulting industrial customers and collecting fees.

In sum, two important aspects resulting from the strategic planning process can be pointed out. First, the planning approach broadened the utilities’ option ranges and specified the need to increase their capabilities. Second, even though all organizations faced a comparable degree of future uncertainty and can potentially consider adopting the same strategic options, each organization chose different strategies. These two aspects will be discussed in the next chapter.

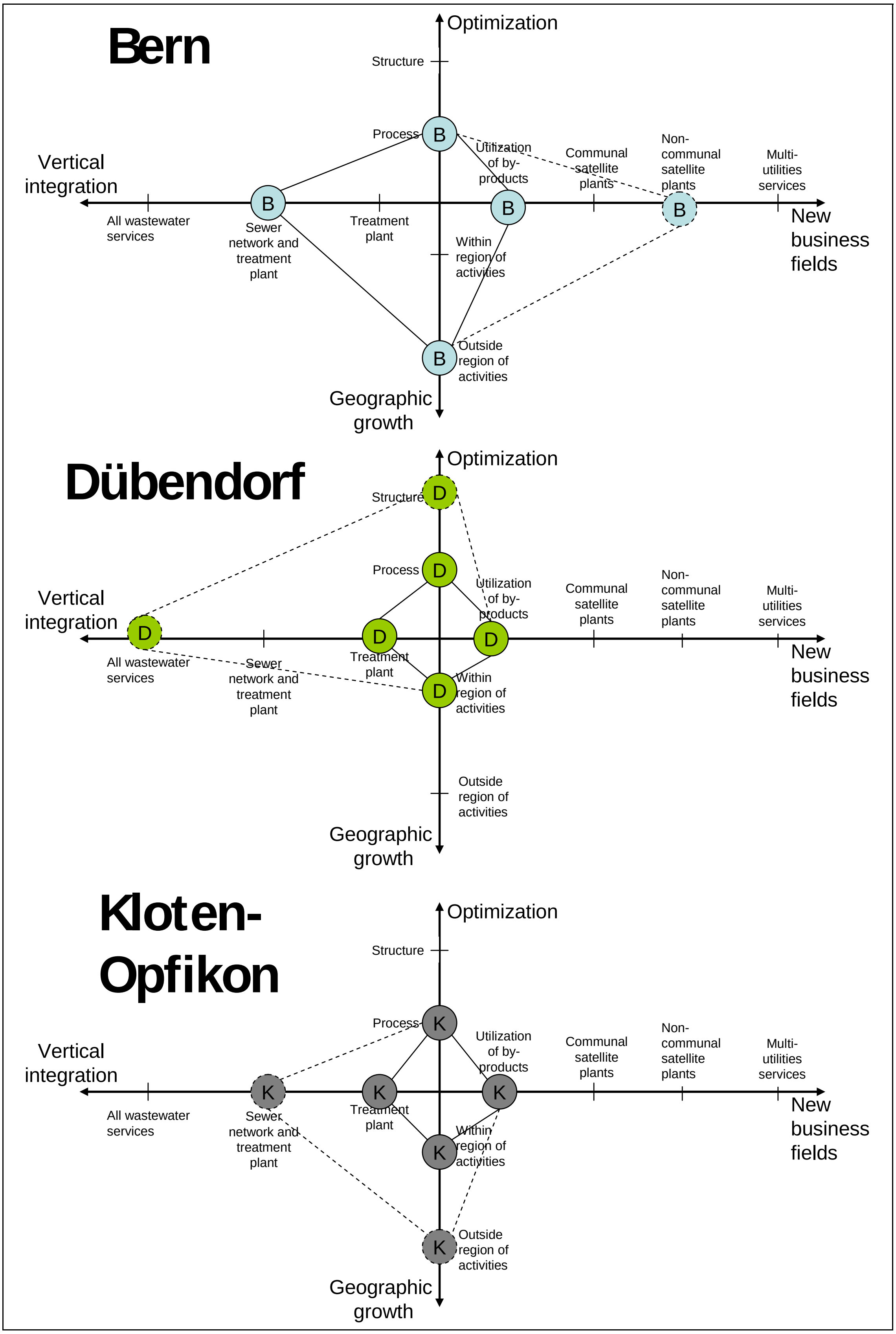

Figure 2 Strategic option spectrum of the case studies (Bern, Dübendorf, Kloten-Opfikon). The full lines and circles represent the strategies implemented before the strategic planning process was conducted. The dashed circles and lines represent the strategic options considered after the process.

6 Discussion

Prior to the strategic planning process, the analyzed utility organizations had focused mainly on developing the technical and managerial capabilities required to operate the infrastructure under given context conditions and objectives. By contrast and partly with the exception of Bern, the key strategic capabilities required to ensure the long term provision of sanitation services were largely missing. The results from the strategic planning process strongly suggest that this gap was closed during the process.

At the end of the process, all participants stated that they were in a better position to identify and understand relevant context developments and assess feasible options and their tradeoffs relative to several objective dimensions. More importantly, this statement was confirmed by a series of initiatives and commitments that were decided by the utility organization. For example, Dübendorf commissioned a consulting firm to develop an organizational model suitable for integrating all wastewater related services and clarify the feasibility and costs of the alternative. Bern, on the other side, decided to clarify the technical and logistic capabilities required for operating satellite plants through the test operation of plants with low financial risks such as small decentralized facilities treating highway drainage. To implement this project, Bern contacted the state authorities responsible for highway drainage treatment and negotiations are taking place aiming at transferring the operation of the corresponding facilities to Bern. Finally, Kloten-Opfikon decided to abstain from renewing part of its infrastructure as it would bind resources for decades to come and thus reduce the possibilities of a future merging with neighboring organizations. Instead, Kloten-Opfikon has undertaken steps to coordinate its upgrading activities with the neighboring organizations. The strategic planning process that the utility organizations underwent can therefore be understood as an organizational learning process. Organizational learning has been identified in the literature as one of the central processes for acquiring and building organizational capabilities (cf. Teece et al. 1997; Zollo and Winter 2002). Thus, interpreting the research findings in the context of this literature supports our general argument that strategic planning processes enable public utilities to adopt organizational capabilities to adequately address future challenges and uncertain developments.

In addition, the strategic planning process increased the decision makers' awareness for the need to accumulate adequate technological and managerial capabilities. In the three case studies, strategies were favored that aimed either at growth (vertical, horizontal, geographical) or at structural changes. Implementing these strategies requires increasing the capabilities available in the organizations. For example, in order to administer all wastewater related services, Dübendorf would have to acquire additional financial and technical know-how especially with regard to sewerage maintenance and financing. As the current organizational structures restrain the acquisition and management of the required capabilities, Dübendorf decided to undergo a restructuring and change its organizational form from a partnership of convenience to a publicly owned stock corporation. By contrast, in the case of Kloten-Opfikon it is unclear so far whether the adopted growth strategy requires a modification of the core organizational structure or if an optimization of the current structure will suffice. Similarly, it remains unclear at the moment whether Bern can attain the technical and logistical capabilities to operate satellite plants under its current organizational structure. In addition, once implemented, these capabilities could induce a further broadening of the scope of activity of the organization. In the Dübendorf case, for instance, participants of the strategic planning process concluded that when setting-up the consulting service for industrial customers, this know-how should also be offered to other wastewater organizations in the region.

Besides these similarities, the divergence in the strategies favored by each organization is rather substantial (see Figure 2). It can be explained by the primary goals of the different organizations. First, Bern was the only company to consider strategic options that increased the horizontal scope of its utility business due to the organization's focus on economic objectives. Options implying a stronger horizontal integration can become a source of substantial revenue, but are of little value if environmental or governance objectives are primarily pursued, as in Kloten-Opfikon and Dübendorf. For a governance objective, a stronger horizontal integration could rather show negative effects, as it would require the communities to share the ownership and control over the utility with other parties. Second, the dominance of governance objectives in Dübendorf, as opposed to the dominance of environmental objectives in Kloten-Opfikon explains why Dübendorf focuses on vertical integration whereas Kloten-Opfikon prefers a geographical growth. A geographical expansion can mobilize economies of scale and would facilitate the achievement of high water protection levels. For Dübendorf, geographical expansion is dismissed mainly because it would require sharing power with other communities.

7 Conclusions and outlook

In this paper, we showed that utilities that are publicly owned and operated can identify the capabilities required to secure the long term service provision by applying adequate strategic planning processes. Therefore, privatization is not a necessary condition for building up the professional resources to address the increasingly complex context conditions. Our findings further revealed that the direction of change initiated by these processes may differ substantially between the cases depending on the preferences of the respective communities. We hope these results help overcome the meanwhile somewhat dated debate about whether private or public provision of utility services is *per se* more appropriate by exemplifying how "sustainable" infrastructure planning can balance competing objectives in a long term perspective.

Based on our findings, we expect an increase in the number and diversity of organizational forms in the future. Strategic planning tools, as the one presented in this paper, will support existing organizations in identifying deficits in their capability structure and thus to embark on more or less radical organizational reform processes. Depending on the primary objectives and the starting conditions of the communities, this will lead to a more pronounced independence of the management and a differing scope of activities between the reformed utilities. Whether these developments will in the long run lead to a single "optimal" organizational paradigm or whether diversity will remain large depends on the actual pressures generated by future context conditions.

There are however a series of limitations to our findings which call for further research. Strategic planning can certainly be applied in very different contexts and situations. However, a minimum requirement at the organizational level is a commitment of the utility management and other stakeholders to both the strategic planning process and the subsequent strategy implementation. Results similar to those in the three cases of this study are hardly to expect without this commitment or the presence of an external source that initiates and drives the process.

Furthermore, utility organizations need at least the capabilities to run, interpret and implement results from strategic planning processes. Limitations in this respect are likely to appear in socio-technical contexts in which institutions responsible for the development and management of the public infrastructures are weak or inexistent. Under such conditions, strategic planning approaches have to be developed further to meet the specific circumstances. Nonetheless, we assume that utility organizations operating under these conditions can also profit from an open and systematic debate of alternatives, future developments and objectives. In our view, the outlook for sustainable infrastructure services provision seems bleak in settings where this assumption does not apply. If conditions make it impossible to run a strategic planning process in public organizations, then it is very unlikely that other mechanisms such as privatization are a viable option for sustainable infrastructure management.

At the sectoral level, we have applied our approach to decision making contexts characterized by high resource commitments, considerable uncertainty and multiple objectives together with high public sensitivity. We believe that these characteristics are typical for many infrastructure sectors. We expect that the proposed strategic planning approach and the results are transferrable to infrastructure sectors exhibiting similar characteristics. These may include water supply, roads and railway systems, and partly the electricity sector, but we have to take into account that decision context characteristics also depend on national, regional and local circumstances. Further research could shed more light on these circumstances and their implications for adapting strategic planning processes.

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Chapter 3

Evolution of a Wastewater Treatment Plant challenges traditional Design Concepts

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Evolution of a Wastewater Treatment Plant challenges traditional Design Concepts

Damian Dominguez, Willi Gujer*
*Corresponding author
Engineering Department, Swiss Federal Institute of Aquatic Science and Technology, Eawag, 8600 Dübendorf, Switzerland and Institute of Environmental Engineering, ETH Zurich, 8093 Zurich, Switzerland
(damian.dominguez@eawag.ch; gujer@eawag.ch)

Abstract
Traditional design and upgrade concepts for wastewater treatment plants (WWTP) are based on the forecasting of load parameters over a period of 25 to 40 years. This approach is adequate as long as the environment of a WWTP is stable or predictable over this long time period. However, these conditions are usually not met, as the catchment area, discharge requirements, available technology and institutional conditions of a WWTP may change drastically over time. The complexity and consequences of these dynamics are shown exemplarily in a case study analysing the historical development of a plant from the initial planning steps to the current date. We conclude that the dynamic and complexity of the wastewater system makes reliable predictions impossible, and therefore question the current design and upgrade approach. Instead, we propose to improve the planning and design of wastewater infrastructures through methodologies that systematically account for future uncertainty, like e.g. scenario planning.

Keywords: Wastewater treatment; design; forecasting; uncertainty; adaptive management; scenario planning

1 Introduction

Professionals working in the field of urban wastewater are often confronted with the disappointing fact that carefully researched measures do not lead to the desired results. The reason for this can often be attributed to unforeseeable social, economical and legal changes.

Nevertheless, consciousness of the long term dynamics in wastewater systems and its importance is not widespread among practitioners and decision makers (Beck and Cummings 1996). Because of this lack of consciousness, structures are designed or upgraded under the assumption that future changes can be taken into account through forecasts. This is highly questionable given the pace of changes and their uncertain consequences on the operation of wastewater structures. The long planning phase and the long operational lifespan of wastewater structures only add to this dilemma.

In this paper we assert that the current design and upgrading practice for wastewater structures is unsuitable in view of the unpredictability of future developments. This uncertainty results from the long term dynamics and complexity of the wastewater system as well as the long planning and operational life of wastewater structures. Moreover, current design procedures can be of such rigidity that they hinder future adjustments (Vanrolleghem et al. 1996). To prove this assertion, we analyze the historical development of an exemplary wastewater treatment plant and its surrounding environment from the initial planning to the current date. The interactions between the evolution of the pollutant loads (phosphorus, chemical oxygen demand (COD)) from the catchment, the development of the plant's capacity and changes in environmental standards are emphasised. From the results of our analysis we deduce weaknesses in the way we typically handle long term future uncertainty and propose scenario planning as an alternative approach.

To be able to understand the development of a wastewater treatment plant (WWTP) through time, it is first necessary to apprehend the system in which it is embedded.

A wastewater treatment plant is part of an urban water system, which consists of a catchment area (households, industry, roads, etc.), a sewer system and a receiving water. As shown in Figure 1, these so called sub-systems of an urban wastewater system are subject to multiple and often complicated interactions. Additionally, they influence and are influenced by legal and socio-economical factors, e.g. new legislation concerning receiving water, public acceptance, saving measures, etc.. The various types of interactions and feedback loops within this socio-technical system make it difficult to understand how single actions affect the entire system (Geldof 1995). Load dynamics and operational changes in a WWTP can therefore only be explained by considering the development of each subsystem and their interactions.

For the sake of simplicity, we regard the catchment area and the sewer system as one sub-system.

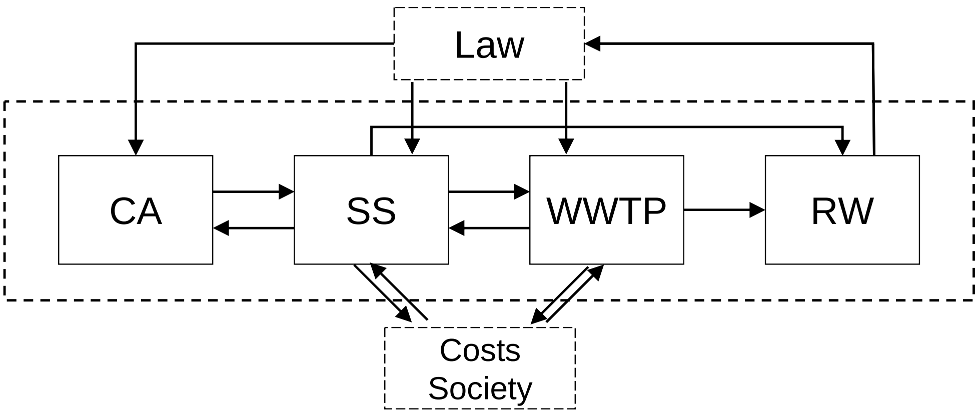

Figure 1: The sub-systems of an urban wastewater system and their interactions: catchment area (CA), sewer system (SS), wastewater treatment plant (WWTP) and receiving water (RW). Law, costs and the society are external driving forces.

2 Case Study

In this case study we analyze the historical development of the WWTP Werdhölzli, located in Zurich, Switzerland. With an influent load corresponding to approximately 600’000 person equivalents (p.e.) it is the largest treatment plant in the country.

The planning and design phase of the plant started in 1972 and lasted until 1981. The nitrification and filtration performance of the plant were based on extensive pilot tests conducted during this phase (see Gujer 1977; Gujer and Boller 1978). The design loads were established in a comprehensive study in 1976 (Zurich Civil Engineering Office 1976) using the available information about past and expected future trends in water consumption and pollutant concentration. After 4 years of construction the plant went into operation in 1985.

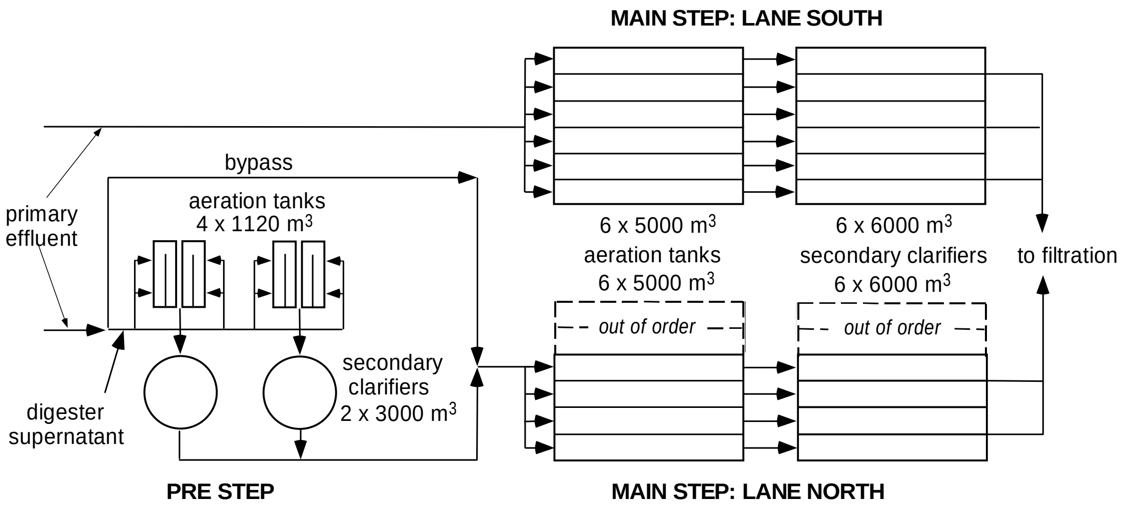

Figure 2: Flow scheme of the WWTP Zurich-Werdhölzli in 1989 (Siegrist et al. 2000). Until 1986 the aeration tanks of the pre step consisted of two equal lanes totaling approx. 9’000 m^3. The southern pre step was taken out of operation in 1986.

Originally designed as a two step plant (see Figure 2), the WWTP has undergone many important changes in the time elapsed since it started operation, an overview of which is given in Table 1. How and why these changes occurred can only be explained under consideration of the dynamics of the entire wastewater system since the 1970’s.

The dynamics of the wastewater system is characterized by the dynamics of its sub-systems and their mutual relationships. In the next sections we will therefore first analyze important developments concerning the catchment area and the environmental standards. Thereafter, we will show how these developments affected the WWTP.

Table 1: Significant changes in operation and performance of WWTP Werdhölzli since 1985 (operation start)

	1985	**2003**
Infrastructure	Two step plant	One step
Activated sludge concentration	2.5-3 kg TSS/m^3	3.8-4.5 kg TSS/m^3
Treatment processes	Nitrification	Nitrification and denitrification
Wastewater treated	Approx. 80% of Zurich’s wastewater	All wastewater from Zurich and de-icing wastewater from the airport

2.1 Developments in the catchment area

The characteristics of the catchment area can change substantially during the long time span between the initial planning and the beginning of operation of a WWTP (i.e. 13 years for Werdhölzli). Changes continue occurring during the operational life of a plant. As seen in Figure 3, the city of Zurich has experienced strong changes in population size, amount of industry and water consumption since the initial planning phase in 1972.

Between 1970 and 2000 Zurich's population decreased by 21% (see Figure 3). Since 1998 efforts are being undertaken to reverse this negative trend (Urban development of the city of Zurich 2004).

As can be seen in Figure 3, the city of Zurich has experienced an employment shift from the second sector (processing of goods) into the tertiary sector (services). This shift is due to structural changes in the Swiss economy that started in the second half of the 1960's and led to the closing, relocating, restructuring or outsourcing of the activities of several companies. As a consequence, industry in Zurich has been decreasing ever since (Bretschger and Klaus 1998).

Water consumption in the catchment area reached its highest value in 1973 (see Figure 3). Since then, consumption has been dropping as a result of water saving measures and the above mentioned economical shifts from industrial to service related activities (Urban development of the city of Zurich 2004).

In addition to these developments, changes in drainage concepts and optimization measures in the wastewater system also had an effect on the catchment area:

The drainage concept of the city of Zurich underwent a re-orientation in the mid 80's. The forceful drainage of all natural water (e.g. rain water, small streams) from the urban area was no longer considered advisable (AWEL 2003, Rauch et al. 2001). Whenever possible, rain water is kept out of the sewer system and unpolluted extraneous water is removed. As seen in Table 2, the extraneous water flow has decreased by approx. 30% since 1985. Reductions of at least the same order of magnitude are expected to have occurred due to restorations of the sewer system (AWEL 2003). The amount of rainwater entering the combined sewer system of Zurich is being reduced through increased local infiltration (Rauch et al. 2001).

Until 2001 Zurich operated two WWTPs. To reduce overall costs the operation of the WWTP Glatt was stopped in November 2001 and the wastewater was re-directed to Werdhölzli. This increased the treated person equivalents from approx. 500'000 to approx. 600'000.

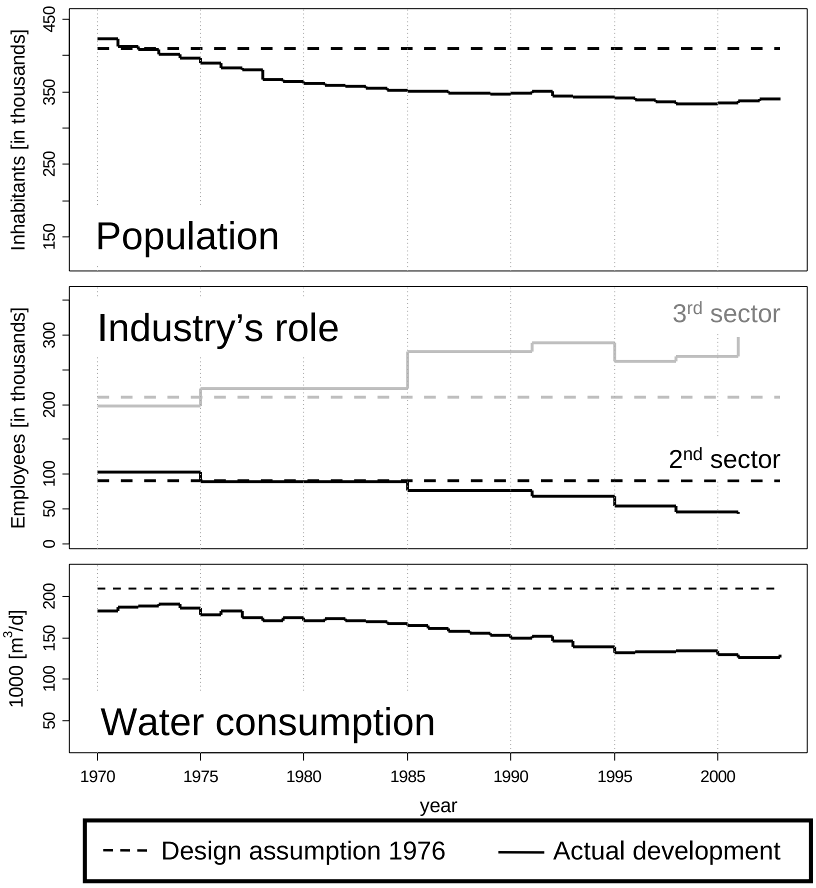

Figure 3: Development of population, industry (employees working in the second and tertiary sector) and water consumption in the city of Zurich for the time span between 1970 and 2003 (Zurich's statistics agency and Statistic City of Zurich). The design values (dashed lines) are included for comparison (Zurich Civil Engineering Office 1976). Planning and design of the plant was done between 1972 and 1981. Operation started in 1985.

Table 2: Estimated extraneous water flow in combined sewers by categories in 1985 and 2003 in the city of Zurich (AWEL 2003)**.**

	Estimated extraneous water flow in combined sewers [l/s]	
	1985	2003
Spring and stream water	250	85
Fountains	65	45
Cooling water	103	88
Seepage water, intruding groundwater	450	385
TOTAL	**868**	**603**

2.2 Development of the environmental standards

Legal environmental standards develop through time due to new scientific insight and changing societal demands. They influence the performance of a WWTP directly (e.g. new performance requirements due to legal changes) or indirectly (e.g. requirements of water saving technologies).

Important changes in environmental standards in Switzerland since 1985 (operation start) include the coming into force of a phosphate ban for detergents in 1986 and a regulation to reduce total nitrogen load in the effluent of WWTPs in the Rhine watershed. The former had a substantial effect on the phosphorous content of the influent, while the latter required upgrading of the WWTP Werdhölzli for denitrification.

2.3 Development of the WWTP

As mentioned before, developments in the catchment area and in the environmental standards can lead to substantial changes of the incoming load and in the operation of a plant. Interestingly, this is not unidirectional as developments in the plant can also lead to changes within the catchment, which again have consequences for the plant. This feedback loop and the different interactions have in time lead to several changes within the WWTP Werdhölzli, an overview of which is given in Table 3. A detailed account on the cause-and-effect chain shows how complex the impacts of load changes and alterations of environmental standards can be.

Table 3: Main process developments of the biological step for the WWTP Werdhölzli in Zurich (Switzerland) for the period 1985-2002 (extended from Siegrist et al. 2000).

Date	Main process development
1985	Start of operation of the WWTP Werdhölzli in two step mode
1989	Stop of operation of aerated pre-step, operation of the plant in single step mode
1993-1997	Gradual installation of anoxic zones in the existing activated sludge tanks (28 % of total volume)
1994-1998	Optimization of the denitrification (reduction of oxygen input and increase of denitrifying sludge blanket in the secondary clarifier)
1996	Reduction of the maximum allowed storm water flow from 9 to 6 m^3/s. This allowed for an increase in activated sludge concentration from 3 to 4.5 kg TSS/m^3 (maximum possible concentration)
2001	Stop of operation of the WWTP Glatt (approx. 100’000 p.e.) in Zurich’s north. This wastewater is now treated by the WWTP Werdhölzli
2002	Treatment of the de-icing wastewater from the airport

Effect of changes in the environmental standards

The phosphate ban in detergents (1986) led to an abrupt decrease in the phosphorous load to be treated by Swiss WWTPs (Siegrist and Boller 1999). This decrease was also observed in Werdhölzli. The phosphorous load measured in the past 14 years has remained constant at approx. 0.7 t/d, well below the design load of 2.2 t/d. The decrease of the phosphorus load led to a reduction of the sludge production from chemical phosphorus precipitation of approx. 10 t TS/d. This is equivalent to an aerated volume of around 12’000

m^3 (or 20 % of the main nitrifying stage) considering the operational conditions at the time and the design parameters.

In 1985 the plant was built as a two stage treatment plant consisting of one fully aerated pre-step (8’900 m^3) and a main nitrifying stage (60’000 m^3). The decrease in sludge production resulting from the phosphorus load reduction made it possible to take the pre-step out of operation in 1989 and hence to save operation costs.

The expected introduction of legal restrictions regarding nitrogen elimination required the installation of a denitrifying stage. This was accomplished between 1993 and 1997 by gradually separating anoxic zones from the total activated sludge volume. At the same time measures to optimize denitrification were conducted (see Table 3). The partition led to the desired nitrogen elimination, but it also implied a decrease of the COD -based operational capacity of the plant (Figure 4, left). This operational capacity is an indicator of the COD load that the plant is able to treat under the prevailing operational conditions. It is a function of the activated sludge concentration, the available aerated volume and the minimal required aerobic sludge retention time for full nitrification.

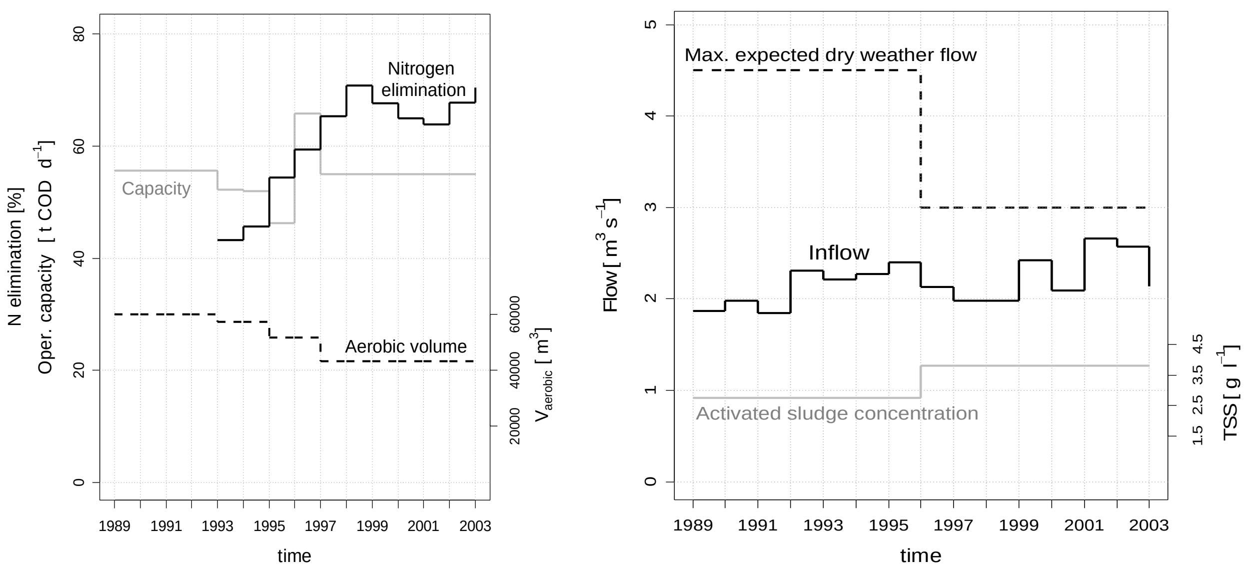

Figure 4: *Left:* Between 1993 and 1997 the aerobic zone was gradually reduced in favor of an anoxic zone. This and other optimization measures led to increased nitrogen elimination. On the other hand, the reduction of aerobic volume led to a visible reduction of the operational capacity of the plant between 1993 and 1996. *Right:* Mean yearly inflow to the WWTP Werdhölzli and the maximum expected dry weather flow of the plant over time. Also depicted is the activated sludge concentration, which could be increased after the reduction of the hydraulic capacity in 1996.

Effect of changes in the catchment area

The mean annual inflow to the WWTP was well below the maximum expected dry weather flow of the plant until 1996 (see Figure 4, right). This overcapacity was the consequence of an unforeseen strong decrease in wastewater flow during the past 30 years due to a decline in water consumption, and measures reducing the amount of extraneous water and rain water in the sewer system. The maximum expected dry weather flow was therefore lowered in 1996.

The decrease of the maximum expected dry weather flow allowed an increase of the suspended solids concentration from approx. 2.75 to 4.5 kg TSS/m^3. As seen in Figure 4, right, the plant is currently operated at approx. 3.8 kg TSS/m^3.

The increase of the suspended solids concentration led to a rise of the plants operational capacity compensating the capacity loss caused by the installation of anoxic zones (compare Figure 5).

The COD load has been decreasing since the mid 90's (compare Figure 5) because of important load contributors (e.g. dairy, breweries and meat processing enterprises) shutting down production in the catchment area. The closing down of the WWTP Glatt and the diversion of its wastewater to the WWTP Werdhölzli in 2001 briefly attenuated the COD load decline.

The COD decrease and the simultaneous increase of the operational suspended solids concentration has led to a growing deviation between operational capacity and incoming load (Figure 5). This difference is a measure of the capacity reserve of the plant.

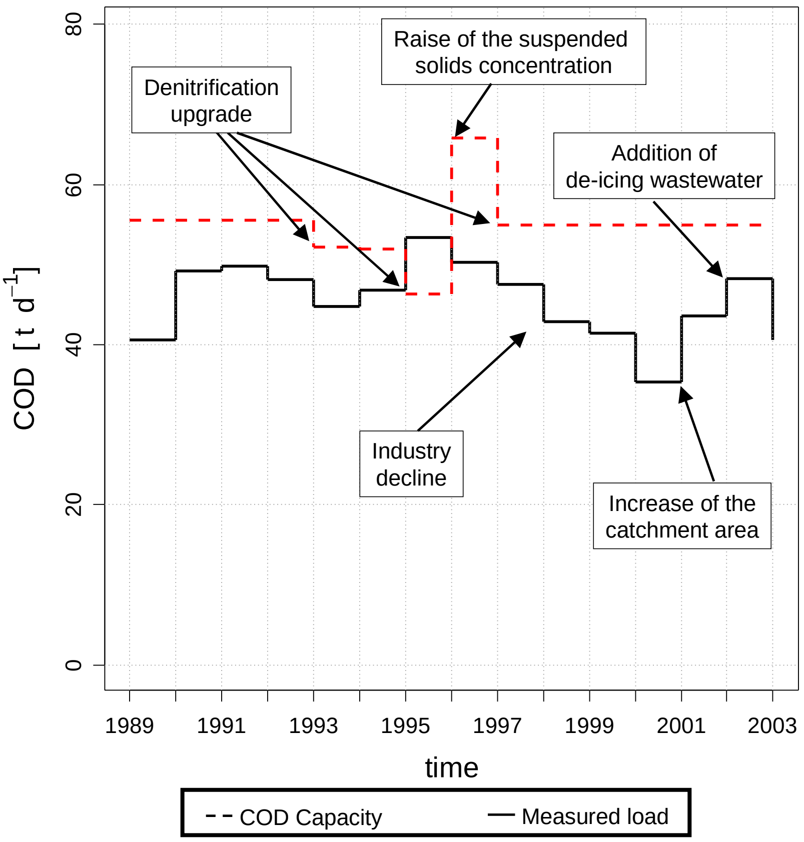

Figure 5: Yearly average COD load measured after the primary clarifier versus the calculated COD capacity of the plant (dashed line). Important events leading to changes of the load and capacity are also displayed. The difference between the two lines is a measure for the capacity reserve of the plant.

Feedback from the WWTP

The presence of capacity reserves in the WWTP Werdhölzli encouraged the merging of the catchment areas of Werdhölzli and Glatt in 2001. This increased the incoming load to WWTP Werdhölzli from approx. 500'000 p.e. to an estimated 600'000 p.e., leading to a reduction of the capacity reserves of the plant (see Figure 5). In other words, a decision based on the available reserves of the plant had an effect on the load to be treated and hence on the available reserves. This feedback or back-coupling could be observed again in the additional treatment of de-icing wastewater.

In 2002 the WWTP Werdhölzli began treating the de-icing wastewater from Zurich's airport, consisting of highly concentrated organic compounds. The consequential rise in the COD load can be observed in Figure 5. Once again, it was the recognition of available capacity reserves which led to this step. An additional incentive was the enhancement of the denitrification rate through the addition of easily degradable COD.

3 Discussion

In this paper, we analyzed the long term dynamics in the development of a wastewater treatment plant (WWTP). The analysis was based on the reconstruction of the historical cause-and-effect chain that led to changes in the plant. We observed strong operational and performance changes, despite the fact that the analyzed time span is only a fraction of the life expectancy of a plant. These operational and performance changes were the consequence of developments in the catchment area and in environmental law influencing the WWTP and a feedback between the plant and these sub-systems. These interactions and feedbacks led to an extreme dynamic development of the investigated WWTP.

The developments in the catchment area and in the environmental standards resulted in a better performance of the plant while retaining a certain amount of capacity reserves. This performance increase was achieved without costly structural alterations. Only relatively modest costs for the installation of volume partitions and additional aeration were necessary.

The development, however, could have been entirely different. Population could have increased strongly over the same period or a highly polluting industrial enterprise could have started operation in the catchment area. Such an expansive development is just as conceivable as the one which actually took place. As seen in this case study, future uncertainty in wastewater systems is very high due to the complexity and dynamic of the system.

WWTPs are typically constructed to be long living and considered as rather static, future uncertainty is hardly considered during the planning and design of a plant: We plan and design infrastructure in the wastewater sector based on forecasts (see e.g. Tchobanoglous and Metcalf & Eddy (Boston) 2003, Qasim 1999), as if we knew what to expect in the future. This has important consequences for the operational life of a plant. An unfulfilled forecast will lead to an over- or undersized plant. While the former produces unnecessary capital and operational costs, the latter can require expensive upgrades of the plant in order to meet environmental standards. These environmental standards, on the other hand, can also change over time, posing new demands on the WWTP. As this possibility is usually not considered during the design phase, plants are seldom built to facilitate future upgrading, which as a consequence may be very costly.

What are the alternatives? More accurate forecasts would require the modeling of the whole wastewater system, a complicated and probably impossible task. Instead, we need to identify the range of future uncertainty and design our plants accordingly. The WWTP Werdhölzli would probably have been designed quite differently if the possibility of a strong decline in the COD load would have been considered in its early planning phases. This development, like the reduction of inflow and the introduction of more constrictive environmental regulations was not unthinkable at the time of design. Today, we lack approaches that acknowledge the relevance and unpredictability of such developments. We are therefore in need of methodologies capable of systematic identification of the relevant factors influencing the long term development of a WWTP, their interactions and possible future developments.

A systematic approach for characterizing long term future uncertainty is scenario planning (Schoemaker 1995, Schnaars 1987), which has been gaining attention in the field of wastewater management as a tool for guiding future oriented decisions (see Truffer et al. 2005, Semadeni-Davies et al. 2005). The central idea of scenario planning is to consider a variety of possible futures that include many of the important uncertainties in the system rather than to focus on the accurate prediction of a single outcome (Peterson et al. 2003). Scenario planning is used in business and policy contexts when the relevant timeframe is extremely long and the uncertainty about the relevant factors and their interactions is high (Ringland 2002). This applies for the operational life of WWTPs, which makes scenario planning a promising option for dealing with the complexity and dynamic of the system. However, research still has to be conducted to demonstrate how and to what extent scenario planning can be applied to our field.

Not analyzed in this paper is the role of changes in management and organizational structures on the development of a WWTP. The WWTP Werdhölzli, for example underwent a drastic reorientation and restructuring in the year 2000. It is now managed as a private enterprise providing a service and the command structure is now flat and process oriented. This has reduced the decision time and established clear competencies and responsibilities among the plant operators.

It is not clear yet to what degree management and organizational structures can encourage the recognition and use of capacity reserves or facilitate the implementation of measures leading to performance improvements. The role of management and organizational structures in the ability of a WWTP to react to changes is still an unanswered question.

The WWTP Werdhölzli was chosen as a case study because, until now, developments in its catchment area and in the environmental standards have had a positive effect on its performance and capacity. This makes it possible to identify the effect of different changes in load and environmental standards on the operation and performance of the plant. This would not have been the case if load and environmental changes would have led to a capacity overload of the plant. Such an overload would have required time consuming upgrades, during which it would have been difficult to observe the effects of other changes. In addition, the WWTP Werdhölzli was chosen because the duration and extent of its planning appears to be representative for a plant of its size.

It may be argued that our findings are strongly case specific. It is true that the dynamics observed in this case study are not representative for all WWTPs. However, we expect all WWTPs and most wastewater structures, to be subject to a certain degree of dynamics, as they are all integrated in socio-technical systems. The variety and complexity of the dynamics does not contradict but rather support the general conclusion of this study.

4 Conclusions

The historical analysis conducted in this study shows the extreme dynamic which WWTPs are subject to during their operational life. The details of these dynamics are unpredictable because of the complexity of the wastewater system. As a consequence, a design approach based on a fixed demanded performance and incoming load is not sufficient. This holds true especially in view of the longevity of wastewater structures and the long period of time elapsing between the planning of a measure and its realization. We therefore need new approaches for characterizing long term future uncertainty. This requirement is emphasized by the increased cost pressure on wastewater infrastructure and future challenges (e.g. micro pollutants and pathogens).

In the future uncertainty about long term developments should systematically be considered to improve the way we plan and design structures in urban wastewater systems.

We consider scenario planning to be a possibility to account for this uncertainty, but research is still needed concerning the applicability of the methodology in our field.

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Chapter 4

WWTPs for the future– Assessing the required flexibility

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WWTPs for the future– Assessing the required flexibility

Damian Dominguez[1,]**, *Bernhard Truffer*[2], *Willi Gujer*[1]
*Corresponding author
[1] Engineering Department, Swiss Federal Institute of Aquatic Science and Technology, Eawag, 8600 Dübendorf, Switzerland and Institute of Environmental Engineering, ETH Zurich, 8093 Zurich, Switzerland (damian.dominguez@eawag.ch; gujer@eawag.ch)
[2] CIRUS Department, Swiss Federal Institute of Aquatic Science and Technology, Eawag, 8600 Dübendorf, Switzerland (bernhard.truffer@eawag.ch)

Abstract
The environment of a wastewater treatment plant (WWTP) usually changes drastically and unpredictably during the 25 to 40 years of its operational life due to new legislative regulations, socio-economic and demographic developments, etc. In order to adapt to these unpredictable changes, the design of a WWTP has to provide a certain degree of flexibility. This requires a framing of the relevant factors that influence the long term development of a WWTP, their interactions and possible future developments. In this study, we advocate the use of scenario analysis as a systematic approach for conducting this framing and assessing the characteristics of the required flexibility. The application and advantages of the methodology are illustrated in the case study of a Swiss WWTP facing a series of challenges due to uncertain future developments in its catchment area. Finally, we discuss the application of scenario analysis in the wastewater sector and important aspects that will have to be considered in the future for its routine application in the sector.

Keywords: infrastructure management; flexibility; future developments; scenario analysis; strategic planning; wastewater treatment plant

1 Introduction

A key component in the design and upgrading of wastewater treatment plants (WWTPs) is the consideration of the environment under which the plant will have to operate. Boundary conditions such as the amount and characteristics of the pollution load, the discharge requirements and social acceptance will determine both the size of the plant and the spectrum of feasible technological and organizational approaches.

However, the environment of a WWTP usually changes drastically and unpredictably during its long operational lifespan (25-40 years) (Dominguez and Gujer 2006). A WWTP will only be able to provide an efficient and reliable service over its entire lifespan if it can adapt to social, economical and regulatory developments over time. This requirement for flexibility must be considered at the design stage, since the possibilities for structural adaptations during the operational life of a plant are limited and usually coupled with considerable expenses.

Structuring the desired flexibility requires information about its characteristics. Thus, we have to identify the key aspects which are to be regarded as uncertain (e.g. incoming load, legal requirements, etc.), including their ranges of uncertainty. Otherwise the flexibility of the WWTP may prove to be inadequate or insufficient. For example, a plant designed with the flexibility to adapt to changes in incoming load caused by population developments will not necessarily be able to adapt to changes in legal criteria (e.g. micropollutant levels, rivershed management regulations). However, it is entirely possible that the latter will change during the operational life of the plant; this would prove problematic if only load flexibility had been considered at the design phase. There is therefore a need for a systematic approach for identifying the relevant developments to which a WWTP might have to respond during its operational life.

At the moment, we lack systematic approaches in the wastewater sector for identifying these key aspects out of the spectrum of possible developments. As a consequence, the ability of a plant to adapt to changes in its environment cannot be shaped systematically.

In this paper, we introduce a two-step formal framework for assessing the changes to which a WWTP may have to adapt during its operational life and the range of possible directions these changes may take. In the first step, the methodology of scenario analysis (see e.g. Schoemaker 1995)) is used to systematically create possible future scenarios of how the boundary conditions of a WWTP could evolve over the next decades. In the second step, the consequences of the different future scenarios for the operational life of a WWTP are analyzed. This analysis allows the determination of the level and range of flexibility a plant will require to adapt to possible future changes. As the use of scenario analysis is not common in the wastewater sector, we will first briefly explain the underlying concept and list the different stages of the methodology. Each stage will be illustrated with the aid of a case study.

2 Scenario analysis: Concept and development procedure

Scenario analysis is a systematic approach for characterizing future uncertainty in the development of a system of interest (Schnaars 1987; Schoemaker 1995). This characterization is achieved through the development of different scenarios of how the future could evolve. The different scenarios illustrate the uncertainties in the analyzed system and are representative of the range of possible future developments. The approach is commonly applied in business and policy contexts when the relevant timeframe is extremely long and the uncertainty about the relevant factors and their interactions is high (Ringland 2002).

Scenarios are derived by identifying the relevant factors influencing the long term development of the system at stake, their inter-dependencies and possible future developments. The procedure consists of three stages (see Figure 1):

Stage 1: Identification of the driving forces
Stage 2: Description of possible future developments for the selected driving forces
Stage 3: Grouping the driving forces into representative scenarios based on the interactions and interdependencies.

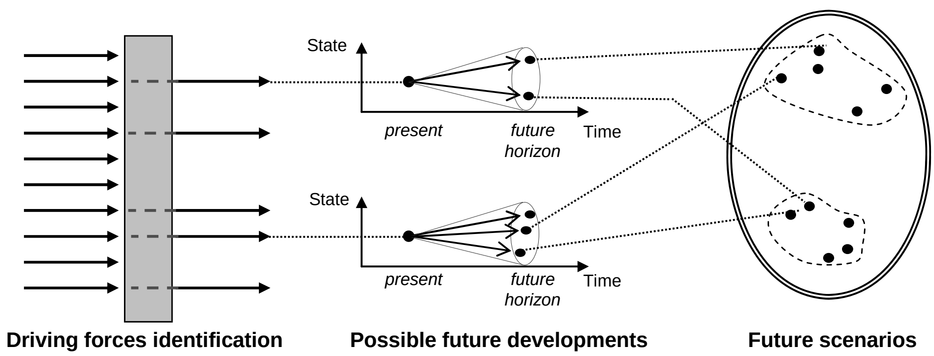

Figure 1 Stages for the development of scenarios: Identification of the driving forces, description of possible future developments and clustering into scenarios free of contradictions (adapted from Gausemeier et al. 1998)

A detailed account of how to carry out the individual steps of the scenario process can be found in Lienert et al. (2006) or Fink et al. (2002). It is important to mention that their approaches are merely propositions of how a scenario process can be conducted. There is not a standard procedure for developing scenarios (Swart et al. 2004) but rather several approaches varying in their degree of complexity and applicability to the planning process. Nonetheless, most of the approaches for developing future scenarios follow the generic steps depicted in Figure 1.

In the following case study, we will briefly describe the system under investigation and then illustrate the development of future scenarios, providing details on the three generic stages of scenario analysis as we proceed.

3 Case Study

3.1 System description: WWTP Kloten-Opfikon

The system for which future scenarios encompassing a time frame of 25-30 years were developed is the WWTP Kloten-Opfikon (approx. 60,000 person equivalents). The plant, located close to Zurich, Switzerland, is currently facing questions concerning the future arrangement of its technical and organizational structures (e.g. technical upgrading and business model). This planning procedure has been complicated by the large uncertainty surrounding the future development of the plant's boundary conditions.

The catchment area is an economically booming region characterized by a high proportion of internationally oriented service enterprises, restaurants and catering, an increasing offering in residential area and the presence of an international airport. These features determine the incoming load, its composition, and diurnal variations. It is unclear how the airport, the job market and the catchment area in general will develop in the next 25 to 30 years. The possibility of the service sector leaving the area is just as likely as further growth. The same applies to the airport, which in the course of international competition could be degraded to a regional airport. This development would not only lead to passenger reduction but also influence the attractiveness of the region for business. In addition to these local questions, there is a high uncertainty in how regional and national issues such as regulatory requirements (e.g. micropollutants) and the market penetration of decentralized technologies will develop in the future (Lienert et al. 2006).

Scenarios were therefore developed to frame the space of possible future challenges and to identify which developments to consider in the planning procedure.

3.2 Development of future scenarios for the WWTP Kloten Opfikon

Stage 1: Analysis of driving forces. The aim of the first step in the scenario development (see Figure 1) is to identify the relevant factors influencing the long range development of the WWTP. This identification is preceded by clearly defining the influence sphere of the scenario user, as scenarios should preferably only consider driving forces outside of this sphere to avoid unnecessary complexity due to e.g. feedback loops (Schoemaker 1995). In the case of the WWTP Kloten-Opfikon, the influence sphere of the plant owner is limited to the plant itself. Developments in the sewer network and the catchment area can only be influenced indirectly, e.g. through recommendations.

Table 1 depicts the forces driving the development of the WWTP Kloten-Opfikon, ranging from waste disposal behavior in the catchment area to discharge regulations. Depending on their specificity, these driving forces can be attributed to the catchment area or the wastewater sector. Additionally, as a complexity reduction measure, we suggest in our formal framework to classify the driving forces into trends and variables. Trends are driving forces whose development is believed to be known with a certain confidence. Variables on the other hand, are driving forces with a highly uncertain future outcome. Variables embody the most important uncertainties of the environment.

Table 1 Forces driving the long range development of the WWTP Kloten-Opfikon. As opposed to trends, variables are driving forces with a highly uncertain future outcome

	Catchment area specific	Wastewater sector specific
Variables	(1) Operation of the airport	(7) Competitive pressure among WWTPs
	(2) Economic development of the city of Zurich	(8) Market penetration of decentralized technologies
	(3) Development of the job market in the catchment area	(9) Regulations for sludge disposal
	(4) Waste disposal behavior in private households	(10) Regulations for wastewater discharge
	(5) Waste disposal behavior in industry, restaurants and catering business	(11) Social acceptability of micropollutants in wastewater
	(6) Sensitivity to wastewater price fluctuations	(12) Charges for discharge of wastewater into the environment
Trends	(I) Decreasing load from airport-related catering business	(III) Withering of federal and state subsidies for wastewater infrastructure
	(II) Constant population in catchment area	(IV) Water saving household devices lead to reductions of up to 20%

Stage 2: Analysis of future developments. In this stage, different possible future developments for the selected variables are described. An example of possible outcomes for the first and third variables of Table 1 can be seen in Figure 2. As depicted in the figure, although the job market in the catchment area has been steadily growing in past years, it is unclear whether this development will continue until the year 2030 (time horizon of the scenarios). Two possible future developments were therefore considered: a boom in the job market, and a decline in the service sector in the catchment area. While several other developments are possible (easing of current growth and maintenance of current enterprises, establishment of new sectors, etc.), these two possibilities represent the range of possible developments and would have the most interesting consequences for the plant's operation.

Stage 3: Scenario creation. In this step, the possible developments of the variables are grouped into scenarios. Care must be taken to ensure that the combinations lead to coherent and clearly differentiated pictures of possible futures. It is necessary that the scenarios are credible and representative of the realm of possible developments.

Figure 2 illustrates how scenarios are developed based on variables one and three (airport and job market) from Table 1. A scenario combining a reduction in the international flights offered at the airport (loss of hub function) with a growing internationally oriented service sector in the catchment area would be implausible. It would be more plausible to assume that the enterprises would relocate to a region with an international airport. This combination plants the seed for the construction of a scenario focusing on airport-related economic development (scenario B from Table 2). A next step to increase the credibility of the scenario would be to include a negative economic development in the region (second variable of Table 1). Hence, a realistic combination of the different realizations of all variables leads to a set of plausible scenarios. The driving forces identified as trends will influence all scenarios.

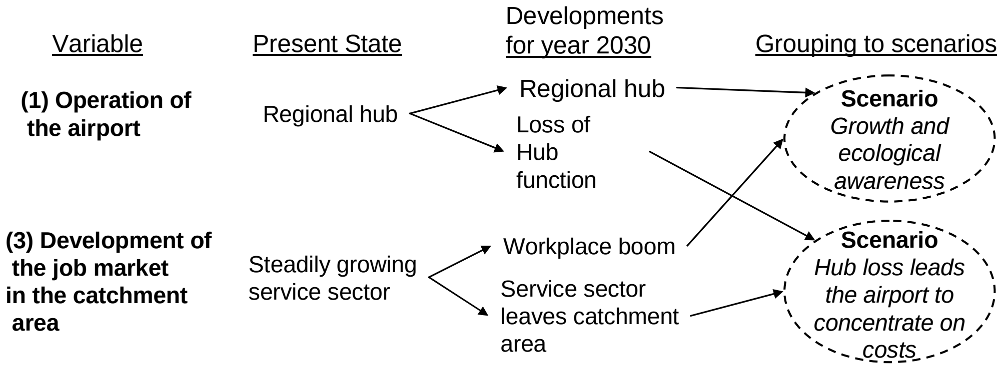

Figure 2 Illustration of the scenario development process for two variables of the case study WWTP Kloten-Opfikon. Selected possible future developments of the variables 1 and 3 are grouped into coherent scenarios. This process is repeated for all variables.

An overview of the scenarios generated for the selected case study is introduced in Table 2. Three plausible and distinct scenarios focus on A) micropollutants, B) airport-related economic developments and C) increasing ecological awareness.

The core of scenario A is the coming into force of regulations requiring an elimination of micropollutants in WWTPs. This development leads to the implementation of decentralized technologies in certain niches (treatment of airplane toilet wastewater, new buildings) and is accompanied by an increased control of discharge and sludge handling by the regulator.

Scenario B is characterized by the loss of the hub position by the airport. The resulting economic drawback increases the cost sensitivity of the airport. Additionally, the hub loss contributes to a decline of the service sector in the catchment area, as it coincides with a negative economic development of the region.

The basis of scenario C is the presumption of strong economic growth in the catchment area, coupled with increasing ecological awareness on the parts of the population and the authorities. The increased weight assigned to waterbody protection leads to the introduction of rivershed management regulations and wastewater discharge tariffs based on management and ecological criteria.

The development of scenarios reduces the realm of possible future developments and combinations to a few plausible and representative pictures of how the boundary conditions of a WWTP could evolve in the future. Each scenario focuses on a different realization of the key uncertainties and has therefore different implications for the plant operation. As discussed in the following section, these scenario-dependant implications form a benchmark, against which the flexibility of a certain WWTP design can be tested.

Table 2 Main elements of the future scenarios of the WWTP Kloten-Opfikon. The title of each scenario emphasizes its focus

Scenario A "Micropollutants as decisive drivers"	**Scenario B** "Hub loss leads the airport to concentrate on costs"	**Scenario C** "Growth and ecological awareness"
• Requirement to eliminate micropollutants in WWTPs • Niche implementation of decentralized technologies (new buildings and treatment of airplane toilet wastewater) • Increased control of discharge and sludge handling by the regulator	• Airport loses hub position • Increased cost sensitivity from the airport side • Service sector leaves the catchment area • Negative economical development of the region	• Strong economic growth in the catchment area • Increased ecological awareness of the population and authorities • Introduction of a rivershed management regulation • Introduction of wastewater discharge tariffs based on management and ecological criteria

4 Assessing the required flexibility through scenarios

Characterizing the realm of possible future developments lays the basis for identifying the characteristics of the WWTP's required flexibility. Future scenarios depict possible realizations of the currently non-influenceable environment of a WWTP, each realization having different consequences for the operational life of a plant. Because of the uncertain nature of the future, it is not possible to predict which scenario is more likely to occur. Thus, a WWTP should be flexible enough to adapt during its operational life to the range of possible futures represented by the scenarios. The required flexibility is described by two attributes: the key aspects which require flexibility and the range to be covered by this flexibility. The key aspects are derived from an analysis of the consequences of the future scenarios for the operational life of a WWTP, while the spectrum to be covered is given by scenario specific realization of these key aspects.

An overview of the key aspects identified for the WWTP Kloten-Opfikon can be seen in Table 3. Besides proximate aspects like possible changes in the incoming load, the scenario consequence analysis also develops awareness for aspects that are often neglected. For example, the range of organizational requirements (fourth key aspect) varies from specific know-how needs (scenario A) to increased coordination requirements (scenario C). Thus, in each scenario the WWTP must cope with different organizational requirements.

As the above example illustrates, the ranges within which the key aspects vary can be inferred from the different scenarios. For example, each scenario represents a different possible future development of the incoming load to the WWTP (see Table 3). The possible developments range from a strong decline in the load (scenario B) which would lead to an undesired overcapacity in the current infrastructure to a difficult to predict increase of the load (scenario C).

In designing the flexibility of a WWTP, the key aspects identified through the scenario analysis and their range of variation must be taken into account. In the case study, a comparison of the possible development depicted in Table 3 with the current technical and organizational structures of the WWTP showed a limited capability to adapt to the possible developments. Additionally, a planned local sludge drying plant was questioned in the face of the high uncertainty concerning the future amount of digested sludge to be treated. In view of these shortcomings, two courses of action are being introduced to ensure future flexibility.

The first course of action is to strive for an increased organizational and technical cross-linking of the different WWTPs within the rivershed of Kloten-Opfikon's receiving water. This includes the attempt to establish a regional solution for the sludge treatment and the coordination of upgrading activities with surrounding WWTPs, whereby leaving the option of a future merging open. This course of action aims at improving the flexibility to adapt to the range of variation expected for the incoming load, the sludge to be processed and the discharge requirements.

The second course of action aims for an operation of the sewer network by the WWTP. Currently the sewer network is operated by the communes independently from one another and from the WWTP. An operation of the sewer network by the WWTP Kloten-Opfikon should increase the capability to adapt to the different organizational requirements identified in the scenario process and to address the possible requirements of the end user more adequately (see Table 3).

Table 3 Consequences for the operational life of the WWTP Kloten-Opfikon derived from the future scenarios (relative to current conditions). The rows represent the key aspects for which flexibility is required, the columns the required range

Scenarios / Key aspects	A	B	C
Discharge regulations	Requirement to eliminate micropollutants	Status quo	Rivershed orientation
Incoming load	Slight decrease of COD-load	Strong decrease of domestic wastewater (less passengers and employees) and gastronomy wastewater Decreasing phosphorous and nitrogen fraction in wastewater Pronounced diurnal flow variation	Strong increase of domestic wastewater (passengers and employees) and gastronomy wastewater Increasing proportion of phosphorous and nitrogen fraction in wastewater Reinforcement of current daily load variations
Sludge processing	Constant. Possibility to treat sludge from decentralized plants for revenue purposes	Reduction of load from WWTPs outside catchment area	Increase in internally produced sludge Sludge load from WWTPs outside catchment area remains constant
Organizational requirements	Professional competence needed for micropollutant treatment and finances	Costs of wastewater treatment becomes a central issue	Coordination with wastewater dischargers in the rivershed (WWTPs, sewerage operators, etc.) and authorities
Focus end-users	Avoidance of micropollutants in water bodies and high micropollutant elimination effectiveness	High cost efficiency within regulatory framework	Environmental protection, especially water body protection

5 Discussion

The creation of scenarios enables a systematic assessment of the flexibility required to cope with possible future developments. This assessment can be used to guide strategic decisions like upgrading requirements or the type of technology to use. Additionally, the use of scenarios adds transparency to the design process, as it provides an argumentation base for deciding which flexibility approaches to favor and why. The fact that it cannot be predicted whether the scenarios will occur at all does not diminish the utility of scenario analysis. The goal of these scenarios is to provide a systematic framework to draw out, challenge and refine knowledge about the future. As such their accuracy can be regarded as secondary (Berkhout and Hertin 2002).

Not to be neglected is the use of future scenarios to broaden one's horizon. Scenarios not only point out social, economic and legal aspects that are often or partially neglected in the planning of wastewater infrastructures. They also emphasize the unpredictability of how these aspects will develop in the future. This is especially important in view of the predominance in the wastewater sector of forecast based approaches for planning and design purposes.

The case study presented in this paper shows how future scenarios for a WWTP can be developed. Efforts are to be taken to generalize the scenario analysis procedure to fit the needs of the wastewater sector. This requires that the methodology be made applicable to different contexts (regional, local, design step, operational life, etc.). It also requires a guide on how to identify driving forces and a systematic approach on how to shape the flexibility of WWTPs to match the required flexibility assessed through the scenarios. This generalization will be the topic of future research.

6 Conclusion

The unpredictability of social, economic and legal developments over a period of 25 to 40 years requires that a WWTP be able to adapt to changes in its environment. This need for flexibility must be considered early in the planning and design phases. The provided flexibility however, has to match the required flexibility. Thus, the first step in preparing for the future is to assess the realm of possible future developments that would be relevant for the plant's performance. We demonstrate that scenario analysis is suited for this task, as it is an effective and conceptually straight forward methodology to perform this evaluation.

The assessment of the required flexibility using scenario analysis has two major advantages. First, the methodology reduces the whole range of possible future developments to a few representative scenarios. This simplifies the evaluation of the flexibility provided by different planning and design alternatives and provides a basis for comparison. Second, the creation of scenarios leads to the identification of developments for which flexibility is required and their uncertainty range.

Future scenarios are tools for assisting strategic decision making. Their aim is not to provide detailed information, as in sizing a WWTP, but to identify relevant possible future developments in a systematic way, to point out directions and to question assumptions. In this context, it must be stressed that the advantages of scenario analysis are not limited to the determination of the required flexibility. In the wastewater sector, decisions taken today will have an effect for decades to come, as infrastructure and organizations are extremely long living and path dependant. Engineers, plant owners and operators can therefore profit from a systematic analysis of possible social, economic and legal developments and their combined impact on plant performance. The consideration of the future is especially important during the planning and design of infrastructures, but also relevant during the operational life of a plant.

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Conclusions and Outlook

General conclusions

In this thesis we investigated the potential of strategic planning for handling the future uncertainty faced by a utility organization. To do so, we developed a series of requirements for strategic planning which are suitable for the infrastructure sector and analyzed and categorized existing strategic planning approaches. Based on this analysis, we developed and applied a strategic planning approach which is suitable for the infrastructure sector and complements the weaknesses of current perspectives to strategic planning. The main conclusions of the work can be summarized as follows:

- The discursive perspective to strategic planning introduced in this thesis can be regarded as a contribution to a more integrated way to handle future uncertainty. A strategic planning approach following this perspective leads to a balanced consideration of objectives and addresses both possible future surprises and alternatives beyond the existing paradigm. Additionally, it leads to an increased awareness for existing tradeoffs and different points of view. By this, it complements the limitations of existing perspectives to strategic planning (a small set of alternatives, a belief in the predictability of future developments over long time periods and only implicit consideration of objectives and tradeoffs).
- Utilities that are publicly owned and operated can identify the capabilities required to secure long-term service provision and adequate strategies for their development by means of an adequate strategic planning process. Privatization is therefore not a requisite for increasing the capacity of utility organizations to adequately address future uncertainty. This conclusion is especially relevant given the persistent opposition against privatization projects in many parts of the world.
- Utility organizations can draw from a variety of alternatives to face future uncertainty. The selected strategies depend on the primary objectives of the carrying communities and the starting conditions of the utility organization, in particular the independence of management. This result suggests that an increasing diversity of organizational forms, integrating elements of private or public organizations is likely to develop over the coming years. Whether these developments will, in the long run, lead to a new dominant organizational paradigm or whether diversity will remain large, depends on the actual pressures generated by future challenges.

Outlook

Some challenging questions for research and practice remain open. These relate to the degree of participation required to conduct the proposed strategic planning approach and the implementation of the strategies assessed.

- This thesis took a pragmatic approach to the degree of stakeholder involvement required to conduct a strategic planning process. Stakeholders from outside of the utility organizations were involved only when they played a key role in setting the strategic direction of the utility, which was the case in only one case study. However, it may be argued that, in public utilities, the involvement of external stakeholders and their different points of view should always be part of a strategic planning process. Although we agree in principle with this criticism, we regard public participation as a means to a better strategic planning and not as an objective by itself. That is, the costs of an extended participatory process should be carefully weighed against its potential benefits. External opinions can also be included, as we did, through other processes like interviews or gray literature research.
- Wastewater utilities were regarded in this thesis as a representative example of utility sectors with highly localized structures, dominant public organizational forms and a high public sensitivity. We expect the proposed strategic planning approach and the results of this thesis to be transferrable to utility sectors exhibiting similar characteristics, such as water, waste disposal and in some cases energy production. However, this assumption remains unproven. Factors like the technological innovation rate, the interactions with other sectors of economic activity, the public awareness for a utility service or the professional stakeholder groups may influence the applicability of the approach to other infrastructure sectors. For example, integrating different points of view when discussing the further development of a water utility can prove extremely difficult as quality criteria tend to dominate the discussion. Therefore, stakeholders lacking a technical expert background may be unable to put their positions and objections forward.
- This thesis regarded the implementation of the results of a strategic planning process as the responsibility of the utility organization. It was assumed that institutions in both the utility organization and the carrying communities were strong enough to implement the strategies assessed. Further research is needed to clarify if this assumption applies or if the implementation step should also be addressed as part of the strategic planning process.
- Closely related to the last point is the question of the applicability of the proposed strategic planning approach in developing countries. Infrastructure issues in developing countries are often characterized by pressing problems such as insufficient sanitation standards or meeting the water needs of a growing population. More importantly, the institutions responsible for the development and management of the public infrastructures are often weak or inexistent. Under these context conditions, the proposed strategic planning approach can not be applied unconditionally but has to be adapted to meet the specific needs (e.g. times and financial budget). Nonetheless, we believe that utility organizations operating under these conditions can also profit from an open and systematic debate of alternatives, future developments and objectives.

Curriculum Vitae

2004 - 2008	Dissertation at the Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf *Handling future uncertainty- Strategic planning for the infrastructure sector*
2001	Internship at the Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf *Supervision of a membrane pilot plant for wastewater treatment*
1998 - 2003	Diploma as Environmental Engineer, ETH Zurich
1993 - 1997	High School, German School, Guadalajara, Mexico
January 31, 1979	Born in Guadalajara, Mexico