POSSIBILITIES OF SCENARIO PLANNING

FOR SANITATION ORGANIZATIONS

FACING DEMOGRAPHIC CHANGE

Dissertation handed in by

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Former wastewatertreatment plant Bernepark
www.bernepark.de / www.grossmax.com

"When a truth is necessary, the reason for it can be found by analysis, that is, by resolving it into simpler ideas and truths until the primary ones are reached."

Gottfried Leibniz

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Content

Summary

The sanitation sector in Germany is challenged by an increasingly turbulent environment. Due to the long use-life of the infrastructure and its capital intensity, the sector is characterized by low rates of return, high fixed-costs and vulnerability to path dependency. This became particularly obvious in the last years within the context of demographic change, when a decreasing population led to the loss of fee payers, and was intensified by a considerable decline in the water demand per capita, which caused increasing wastewater fees. The traditional planning instruments in the sanitation sector rely mainly on forecasts and forward projections, while disregarding key dynamics of the surrounding political-legal, economic, societal, technological and environmental framework conditions.

Therefore, this dissertation assesses if the low adaptive capacity of the sanitation sector, which became obvious with demographic change, can be enhanced by strengthening the long range planning competencies by means of scenario planning. The dissertation evaluates the possibilities of scenario planning as alternative planning instrument and explores the predictive as well as the explorative possibilities in two separate research streams. The predictive research stream analyzes the specific impacts of demographic change on wastewater fees. The focus lies on a short time horizon and one specific trend. The latter explorative research stream is addressed by a Delphi-based scenario study, in which the most relevant future challenges of the sanitation sector are identified and summarized in four scenarios.

Zusammenfassung

Der Abwassersektor in Deutschland sieht sich mit zunehmend dynamischen Rahmenbedingungen konfrontiert. Auf Grund der langen Nutzungsdauer ihrer Infrastruktur und ihrer Kapitalintensität ist die Abwasserwirtschaft durch hohe Fixkosten und durch ihre Anfälligkeit gegenüber Pfadabhängigkeiten charakterisiert. Dies zeigt sich besonders im Zusammenhang mit den Auswirkungen des demografischen Wandels in den letzten Jahren, in Folge dessen abnehmende Bevölkerungszahlen zu einem Verlust von Gebührenzahlern geführt haben. Zusätzlich wurde dieser Effekt durch einen beträchtlichen Rückgang der Wassernachfrage pro Kopf verstärkt. Die herkömmlichen Planungsansätze in der Siedlungsentwässerung basieren hauptsächlich auf Prognosen und Trendfortschreibungen und berücksichtigen somit nur unzureichend sich ändernde Rahmenbedingungen.

Aus diesem Grund untersucht diese Dissertation inwiefern die geringe Anpassungsfähigkeit, die im Zusammenhang mit dem demografischen Wandel offensichtlich wurde, durch eine Stärkung der strategischen Planungskompetenzen, und speziell durch die Anwendung der Szenarioplanung, erhöht werden kann. Hierfür werden sowohl die prediktiven als auch die explorative Möglichkeiten der Szenarioplanung bewertet. Im ersten prediktiven Ansatz liegt der Fokus auf den spezifischen Auswirkungen des demografischen Wandels auf die Abwassergebühren. Der zweite explorative Ansatz basiert auf einer Kombination der Delphi-Technik mit der Szenarioplanung, in der die bedeutendsten zukünftigen Herausforderungen identifiziert und in vier Szenarien zusammengefasst werden.

Affiliations

My dissertation is affiliated with two important research institutions in Dresden: the Chair of Environmental Management and Accounting, Faculty of Business and Economics at the Technische Universität Dresden and the Dresden Leibniz Graduate School (DLGS).

During my time as a research associate at the Chair of Environmental Management and Accounting I was involved inter alia in the third party project "Impacts of demographical change on the drainage of settlements (DEMOWAS)" in cooperation with the Institute of Urban Water Management, Technische Universität Dresden, which was financed by the Federal Ministry of Education and Research, the Free State of Saxony and the Emschergenossenschaft.[1]

My second affiliation is the Dresden Leibniz Graduate School, which is an international graduate school of spatial science, economics and social sciences in Germany. The Dresden Leibniz Graduate School is a joint activity of the Leibniz Institute of Ecological and Regional Development, Technische Universität Dresden and the Academy for Spatial Research and Planning.[2]

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1 See also http://tu-dresden.de/die_tu_dresden/fakultaeten/fakultaet_wirtschaftswissenschaften/bwl/bu/ and www.demowas.de

2 See also www.dlgs-dresden.de

1 Framework of the Cumulative Dissertation

In this cumulative dissertation the possibilities of scenario planning for urban drainage organizations facing demographic change are analyzed. Demographic change is dealt with in this dissertation mainly from two perspectives: as a cause and as an effect. Demographic change in terms of a decreasing population is the cause of overcapacities and has a consequence of rising wastewater fees. But the demographic change complexity is also an indicator of the low long range planning capacities of the sanitation sector that made the sector vulnerable to changing framework conditions such as demographic change. From this latter perspective, demographic change is only one of a multitude of potential future challenges, albeit the main motive for this dissertation.

Based on several published journal articles the issue is analyzed from multiple perspectives. These first overview chapters (1.1 - 1.4) explain the framework of the dissertation and introduce the methodological background of scenario planning; Chapter 1.5 presents the overall research design and the abstracts of the individual journal articles. The individual journal articles can be found in chapters 2 to 7. In chapter 8 some concluding remarks are made.

1.1 Scenario planning as alternative planning instrument[3]

In recent publications [*Beuhler,* 2003; *Dominguez et al.,* 2006; *Dominguez and Gujer,* 2006; *Hiessl,* 2003; *Hillenbrand et al.,* 2010; *Means et al.,* 2005; *Phelps et al.,* 2001], scenario planning is proposed as an appropriate instrument to handle uncertainty in the wastewater sector. Dominguez et al. [2006] support the use of scenario planning in the urban drainage sector. They are calling for change in the current practice of capacity planning of a wastewater treatment plant (WWTP). The methods calculating the capacity of a wastewater treatment plant which are currently in use often disregard key dynamics of the system. Unforeseeable economic, social, or legal changes lead to over- or undercapacities.

> *"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. The long planning phase and the long operational lifespan of wastewater structures only add to this dilemma."* [*Dominguez and Gujer,* 2006]

'Scenario planning is one of the most promising long range planning approaches that supports decision-makers bridging this gap and to overcome the difficulties of traditional planning instruments. [*Miller and Waller,* 2003; *Phelps et al.,* 2001; *Schnaars,* 1987; 2001; *Schoemaker,* 1991; 1993; 1995; *Schwartz,* 1998; *Slaughter,* 2002a; *Slaughter,* 2002b]'[4]

[3] This introduction is based in parts on a further developed paper that was presented at the IHDP Open Meeting 2009, 7th International Science Conference on the Human Dimensions of Global Environmental Change in Bonn [*Nowack and Guenther,* 2009]. A more developed version was published in the anthology on the occasion of the Waterday workshop in Berlin [*Nowack and Gunether,* 2010].

[4] Extract from journal article E3.

1.2 Looking back in history

The first ancestors of scenarios are identified by Bradfield et al. [2005] in Plato's description of his ideal "Republic" as well as in the works of Thomas More and George Orwell. Scenario planning was first mentioned by military strategists in Prussia in the 19th century by Clausewitz and Moltke. Early scenario techniques were developed during the Cold War by the Rand Corporation as a spin-off of the US Airforce and the Douglas Aircraft Company. At the Rand Company Herman Kahn developed scenarios for the Air Defense System Missile Command. Herman Kahn is often seen as the father of modern scenario planning. Pierre Wack, who used Kahn's method at Royal Dutch Shell, realized the first well documented business application of scenario planning. At the same time General Electric also experimented with scenarios, but did not discuss it as openly as Royal Dutch Shell did. [*Wack,* 1985]

1.3 Definitions

As scenario methods were mainly driven and developed in very different disciplines and adopted by many different practitioners terms are not clearly defined. They are used in very different ways and therefore it is necessary to be precise in its terminology.

In this dissertation I define a scenario as a "*description of a possible future state* [of the analyzed system]" and adopt thereby the definition of the Intergovernmental Panel on Climate Change (IPCC) [2000]. Scenario planning describes the entire process of developing scenarios. An important part of scenario planning is the scenario approach, e.g. the number of steps that are necessary to undertake a scenario planning project. "*The* [scenario] *approach consists of an ordered series of steps to accomplish the objectives of the* [scenario planning] *project.*" [*Bishop et al.,* 2007] Scenario techniques are different instruments used in scenario planning in order to facilitate the process and to ameliorate the outcome. In my dissertation, I relied mostly on the generic foresight approach of Bishop et al. [*Bishop et al.,* 2007], who use six steps for a complete scenario planning study and include the two main phases of scenario planning: scenario development (step 1-3) and scenario transfer (steps 4-6). In the scenario development phase, the scenarist visualizes different states of the future; in the scenario transfer phase, the consequences for today's decisions are derived (see also Figure 1).

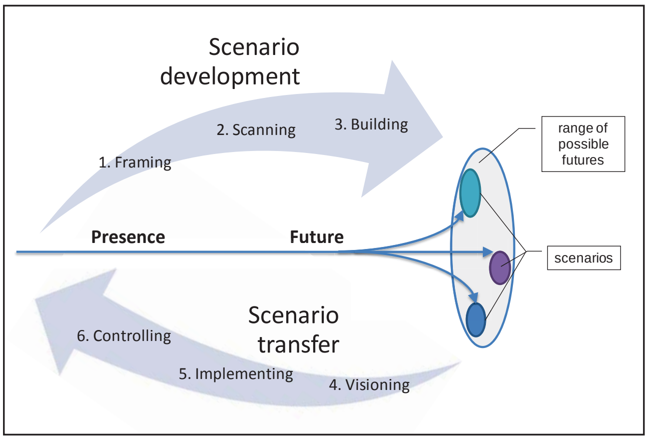

Figure 1: The Generic Scenario Approach

(Adopted from [Bishop et al., 2007; Chermack et al., 2001; Geschka and Hammer, 1997])

The generic scenario process consists of the following steps:

Scenario development

1. **Framing**: The purpose of this step is to shape the project according to the attitude of the audience, the work environment, the rationale, the purpose, the objectives, and the teams. The outcome of this step is a project plan.
2. **Scanning**: Here all relevant information about the system, history and context of the issue is collected. The product, at the end of this step, is information about trends and drivers.
3. **Forecasting**: This step identifies the key drivers and uncertainties and integrates them in a systematic manner into the scenarios. The scenarios clarify the implications and outcomes of the trends and drivers.

Scenario transfer

4. **Visioning:** In the visioning phase, a strategy has to be worked out with respect to how to deal with future challenges. Based on the scenarios, the consequences for today's decisions have to be drawn.
5. **Implementing:** The necessary resources must be organized, and the plan must be implemented and communicated.
6. **Controlling:**[5] Once the plan is implemented, fulfillment of the goals must be evaluated continuously. Furthermore, this process should be iterative; if new information about the future becomes available or new challenges arise, the scenario development should be repeated.

[5] This step differs from the generic scenario approach of Bishop et al. [2007]. The original name of this step was "acting".

1.4 Methodological Introduction

Like the origins of scenario planning, there is also confusion over the different methods of scenario planning which have been used over the years. The reason is, once again, that practitioners of different disciplines adapted the scenario idea to their specific needs and did not apply a certain standard methodology. The result is a vast number of different methods. One reason might be the dualism of the futurists and the scientific scenario planners. Even in one of the most cited scenario studies throughout the world, the reports of the Intergovernmental Panel on Climate Change (IPCC), the theory of scenario planning seems to be neglected. Nordlund [2008] attests a lack of integration of "foresight research" in IPCC reports.

Martelli [2001] describes the situation as "methodological chaos." Current research attempts to categorize and systemize the different scenario typologies and techniques. [*Bishop et al.,* 2007; *Bradfield et al.,* 2005; *Börjeson et al.,* 2006; *Chermack et al.,* 2001; *Godet,* 2000; *Lempert et al.,* 2009; *Malaska et al.,* 1984; *Mietzner and Reger,* 2005; *Nowack et al.,* 2011; *van Notten et al.,* 2003; *Varum and Melo,* 2010]

Van Notten et al. [2005] propose an updated scenario typology, which categorizes scenarios by using overarching themes. The overarching themes describe the key aspects of scenarios, the project goal (why?), process design (how?) and the scenario content (what?).

The categorization of Börjeson et al. [2006] distinguishes between a predictive scenario goal (what will happen?), an explorative goal (what can happen?) and a normative scenario goal (how can a specific target be reached?).

Predictive (probable) scenario projects are dealing with the most likely events. A specific development is expected to occur, and the predictive scenario project aims at assessing the impacts. Estimated challenges and opportunities are highlighted and prepared for the decision-maker. Essential for predictive scenarios is the focus on analyzing and calculating the impacts of a small number of trends. [*Börjeson et al.,* 2006]

Explorative (possible) scenarios, on the other hand, are more long-term oriented. The main focus is the identification and analysis of possible future challenges. Explorative scenarios try to find out what the future could look like. [*Börjeson et al.,* 2006]

Normative (preferable) scenarios focus on a certain objective. For example, a watershed agency is concerned about how to achieve the goal of a good watershed status by 2015 as demanded by the EU Water Framework Directive. [*European Parliament and European Council,* 2000] Normative scenarios investigate if and how this goal can be realized if important elements of the current situation change. I argue that this categorization is inconsistent because normative aspects can be integrated either in predictive or in explorative scenarios in the scenario transfer phase of scenario planning (see Figure 1). Therefore, I exclude normative scenarios as a category from my further analysis.

Bishop et al. [2007] categorize scenario projects using different groups of scenario techniques. Their categories, explained below (see Box 1), are: judgment, baseline, elaboration of fixed scenarios, event sequences, dimension of uncertainty, cross-impact analysis and modelling.

Box 1: Groups of Scenario Techniques [Bishop et al., 2007]

Elaboration of fixed scenarios: A small number of scenarios is prepared ahead of time, for example a green future scenario, a high tech scenario and a depression scenario, etc. Afterwards, the logic of the scenarios is discussed and the impacts on specific domains (law, politics, family life, mobility, public services, etc.) have to be discussed. This method helps to focus on the implications and its consequences and avoids struggling with future uncertainties.

Event sequences: This technique is based on the idea that the future is a sequence of events. An event might happen with a certain probability and leads to further specific events with specific probabilities which are followed by other specific events and so on. Plotted in a probability tree, the most likely future can even be computed.

Backcasting: The starting point of backcasting techniques is a specific image of the future or a vision. For example, every person on earth has access to safe drinking water. Decomposing this goal in its components helps to identify the steps that are necessary to realize this goal.

Dimensions of uncertainty: The starting point for scenario development is the uncertainties of key drivers. Based on these uncertainties, alternative scenarios are constructed. The most famous representative of this technique is Schwartz (1998). The technique is also known as the GBN matrix, which considers two key uncertainties. The morphological analysis and field anomaly relaxation are extensions of the GBN matrix and include more than two key uncertainties.

Cross-impact analysis: The main idea of the cross-impact analysis is that the occurrence of an event will change the probabilities of the occurrence of other events. In the column of a matrix a list of possible events is enumerated. Each event has its starting probability. In the line of event 1, to each of the other events [2,..,n] is assigned a probability, assuming that event 1 has occurred. The same procedure is continued for each event. Afterwards, a random probability between 0 and 1 is chosen. Each event with a probability higher than this random probability is assumed to occur. A distribution of probabilities results by repeating this procedure several times. This can be used to estimate the probability of an event, given that the possible occurrence of the other events is known [*Huss and Honton,* 1987].

Modelling: The bases for these techniques are mathematical models or equations. Each model consists of a set of assumptions. A certain set of different assumptions of the model constitutes one scenario. This can be done in order to promote the complex illustration of the result. The trend impact analysis (TIA) is one of the representatives of this category of techniques. It was developed by Ted Gordon [1994] and considers the effects of perturbing events. Generally, modelling techniques are used to identify baseline scenarios.

Courtney [2003] makes an important contribution by underlining that the scenario design, and thus, the used techniques should be chosen up depending on the type of uncertainty. If uncertainty can be operationalized and the time horizon is not too long, more predictive oriented designs such as modelling in combination with sensitivity analysis, might be more appropriate than more qualitative oriented scenario workshops. The latter option might be more appropriate if the time horizon is more long-term oriented and uncertainty is much more abstract.

In the following the core characteristics are synthesized. It can be stated that an important characteristic of a scenario project is its goal, design and content. [*van Notten et al.,* 2003]

The goal can be explorative or a predictive. [*Börjeson et al.,* 2006; *van Notten et al.,* 2003] The scenario design is determined by the scenario techniques that are used. [*Geschka and Hammer,* 1997; *Huss and Honton,* 1987; *Mietzner and Reger,* 2004] Obviously, not every technique might be appropriate for every scenario goal. Using the technique typology of Bishop et al. [2007], baseline, modelling and event sequences are clearly more predictive oriented, whereas judgement techniques, elaboration of fixed scenarios and backcasting are more of an explorative nature. These techniques are goal-dependent; or in the terms of Börjeson et al. [2006] generating or integrating techniques. Some techniques have an additional function. They are not necessary but can help to deal with some methodological problems. For example, a high degree of driver independency can be evaluated using the cross-impact analysis. The dimension of uncertainty techniques are especially advantageous if a large number of drivers have to be weighed. These techniques are content-dependent. Börjeson et al. [2006] designate these techniques as consistency techniques.

1.5 Research Design

In this part I explain the research design of my dissertation by which I assess the possibilities of scenario planning for urban drainage organizations facing demographic change. After a short introductory research stream the possibilities are analyzed in a predictive as well an explorative research stream as illustrated in Figure 2.

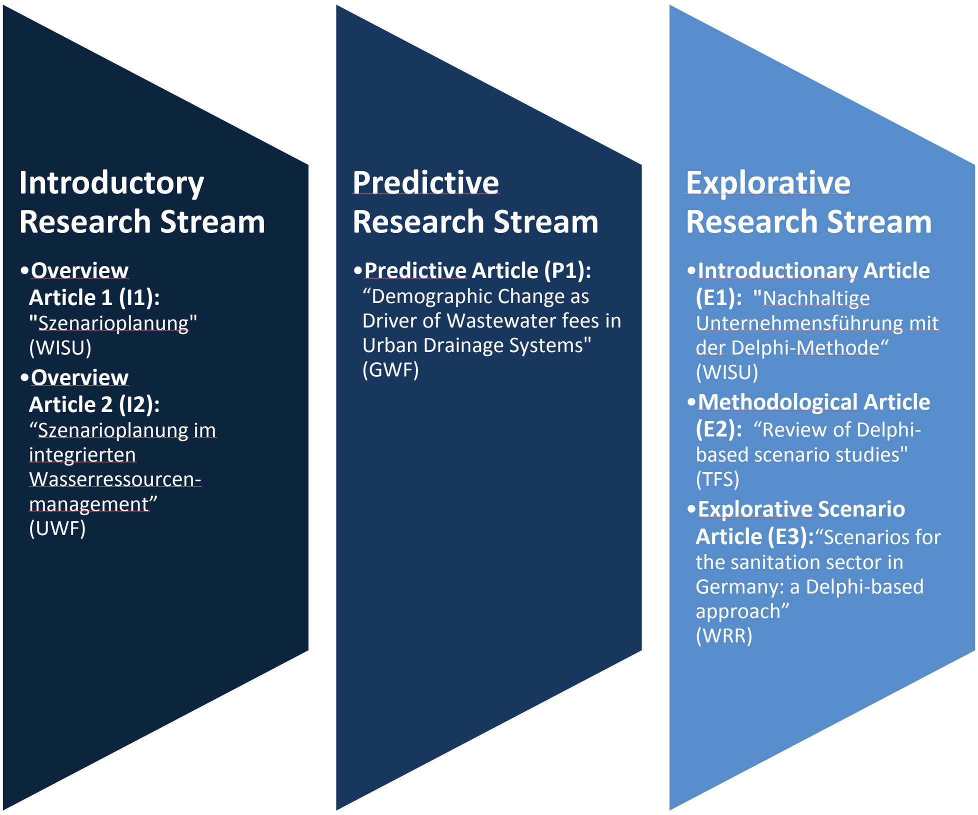

Figure 2: The Overall Research Design

1.5.1 Introductory Research Stream

In the first part of the dissertation two articles give a short overview of the general possibilities of scenario planning in the sanitation sector and in the context of Integrated Water Resource Management. Journal article I1: "Szenarioplanung" published in "Das Wirtschaftsstudium" (WISU), Vol. 38 (2009), No. 3/09, p. 340-341 and journal article P2: "Szenarioplanung im integrierten Wasserressourcenmanagement" published in "UWF – UmweltWirtschaftsForum", Vol. 17, (2009), No. 3, p. 251-255 belong to this research stream.

1.5.1.1 Journal Article I1: Scenario Planning

Günther, Edeltraud / Nowack, Martin, published in: Das Wirtschaftsstudium, Vol. 38 (2009), No. 3, p. 340-341.

Energy crises, globalized world markets and deregulation, as well as demographic and climate change are new arising challenges that companies have to face. Decision-makers in private companies as well as in public organizations must evaluate the impacts of these trends but also manage risks, and seize business opportunities. Illustrated by the example of the sanitation sector the possibilities of scenario planning are outlined.

Szenarioplanung*[6]

Günther, Edeltraud, Nowack, Martin, veröffentlicht in: Das Wirtschaftsstudium, Jg. 38 (2009), Heft 3, S. 340-341.

Energiekrisen, globalisierte Weltmärkte und Deregulierung, aber auch demografischer Wandel und Klimawandel stellen Unternehmen vor neue Herausforderungen. Für Entscheidungsträger in privaten Unternehmen und öffentlichen Einrichtungen stellt sich die Frage, wie einerseits die Konsequenzen dieser Trends zu bewerten sind und wie andererseits Risiken vermindert und sich ergebende Geschäftsmöglichkeiten wahrnehmen können. An Hand der Abwasserwirtschaft werden die Möglichkeiten der Szenarioplanung skizziert.

[6] The original title of the journal article is marked by an asterisk.

1.5.1.2 Journal Article I2: Scenario Planning in the Context of Integrated Water Resources Management

Nowack, Martin / Günther, Edeltraud, published in: uwf - UmweltWirtschaftsForum, Vol. 17 (2009), No. 3, p. 251-255.

Climate, demographic and technological change and their impacts, as well as changing environmental framework conditions will confront Integrated Water Resources Management in the future with major challenges. Scenario planning captures future developments and trends and illustrates them in scenarios, i.e. in possible future pictures with the aim of deriving consequences for today's decisions. The objective of this article is to evaluate the possibilities of scenario planning for Integrated Water Resources Management.

Szenarioplanung im Integrierten Wasserressourcenmanagement*

Nowack, Martin / Günther, Edeltraud, veröffentlicht in: uwf - UmweltWirtschaftsForum, Jg. 17 (2009), Heft 3, S. 251-255.

Klimawandel, demografischer und technologischer Wandel und deren Folgen, aber auch andere sich ändernde Rahmenbedingungen werden das Integrierte Wasserressourcenmanagement (IWRM) in Zukunft vor große Herausforderungen stellen. Die Szenarioplanung erfasst zukünftige Entwicklungen und Trends und illustriert sie in Szenarien bzw. Zukunftsbildern mit dem Ziel, daraus die Konsequenzen für heutige Entscheidungen abzuleiten. Ziel dieses Artikels ist es daher, die Möglichkeiten der Szenarioplanung als integrierende Methode insbesondere im Hinblick auf das Integrierte Wasserressourcenmanagement zu untersuchen.

1.5.2 Predictive Research Stream

In the next research stream the possibilities of scenario planning in a predictive context are analyzed. The research question (RQ) in this research stream is:

RQ1: What are the possibilities of predictive scenario planning?

In this predictive research stream I focus on one specific trend, namely demographic change. More precisely I analyze the economic impacts of demographic change on the sanitation sector. Thus, I deal with demographic change as a cause. The content is rather complex, the focus lies on one trend but also must be compared with other effects. The research design relies on modelling techniques; more precisely a ceteris paribus analysis will be combined with a sensitivity analysis. This research stream is dealt with in the journal article P1: "Demographic Change as Driver of Wastewater fees in Urban Drainage Systems – A Comparison of Demography, Water Saving, Maintenance Cost, Operating Cost and Industry Effects" published in gwf Wasser/Abwasser, Vol. 11 (2010), No. 151, p. 1076 -1085.

1.5.2.1 Journal Article P1: Demographic Change as Driver of Wastewater Fees in Urban Drainage Systems:

A Comparison of Demography, Water Saving, Maintenance Cost, Operating Cost and Industry Effects

Nowack, Martin / John, Sebastian / Tränckner, Jens / Günther, Edeltraud, published in: gwf Wasser/Abwasser, Vol. 11/2010, No. 151, p. 1076 -1085.

Decision-makers in the wastewater industry face demographic changes in terms of a decreasing population and a declining quantity of wastewater. This results in technical hurdles and economic challenges. The economic challenges are caused by the durable and capital intensive infrastructure that can only be adapted to a very limited extent to the changing environment. The fixed costs add up to 75 – 85 % of the total costs and they have to be covered by a reduced number of fee-payers, causing an increase of the wastewater fees per capita. This article analyzes three case studies for the following questions: how strong a wastewater company is affected by demographic change? How will their wastewater fees increase due to demographic change? What is the impact of other effects? Therefore a tool to predict the wastewater fees was developed that considers the population decrease, the wastewater quantity, as well as the development of the costs and the specific tariff system.

Der demografische Wandel als Gebührentreiber in der Siedlungsentwässerung:

Ein Vergleich des Demografieeffektes mit Spar-, Betriebskosten-, Kapitalkosten- und Industrieeffekten*

Nowack, Martin / John, Sebastian / Tränckner, Jens / Günther, Edeltraud, erschienen in: gwf Wasser/Abwasser, Jg. 11/2010, Heft 151, S. 1076 -1085.

Der demografische Wandel in Form einer sinkenden Bevölkerungszahl und eines rückläufigen Abwasseranfalls stellt die Abwasserentsorger neben technischen Aspekten vor eine große wirtschaftliche Herausforderung. Die langlebige und kapitalintensive Infrastruktur kann nur in begrenztem Maße an den demografischen Wandel angepasst werden. Der hohe Fixkostenanteil von 75 – 85 %, der auf eine verringerte Gebührenbasis umgelegt werden muss, droht die Gebühren entsprechend zu erhöhen. Dieser Beitrag untersucht an Hand von drei Fallstudien, wie stark die Abwasserentsorger vom demografischen Wandel betroffen sind und wie sich ihre Abwassergebühren auf Grund des demografischen Wandels oder anderer Effekte zu erhöhen drohen. Hierzu wurde ein Gebührenprognose-Tool entwickelt, das sowohl die Bevölkerungsentwicklung, den Schmutzwasseranfall als auch die Kostenentwicklung und das spezifische Gebührenerhebungsverfahren berücksichtigt.

1.5.3 Explorative Research Stream

In the third research stream, the explorative one, the possibilities of scenario planning in an explorative background are evaluated. The research question that will be answered in this research stream is:

RQ2: What are the possibilities of explorative scenario planning?

Demographic change is dealt with in this research stream as an indicator of low long range planning capacities. It is one possible effect of changing environmental conditions and one challenge among a multitude of others. The focus lies on the identification of possible future challenges or drivers of the development. The content will be rather complex, since in addition a multitude of drivers, driver interdependencies are also to be expected. Therefore, the integration of expert knowledge is assessed as an appropriate method to deal with this complexity. I do so by integrating the Delphi technique into my research design. The Delphi technique itself is shortly introduced in journal article E1: "Nachhaltige Unternehmensführung mit der Delphi-Methode" published in „Das Wirtschaftsstudium", Vol. 40 (2011), No. 4/11, p. 510-511.

An important part of this explorative research stream is the development of a new scenario methodology that is well suited for the high degree complexity of the sanitation system and at the same time capable of assuring a high degree of stakeholder participation. Therefore, journal article E2 "Review of Delphi-based scenario studies: Quality and design considerations," published in "Technological Forecasting and Social Change" (article in press, corrected proof) systematically reviews scenario studies that combined the Delphi technique and scenario planning.

Based on this systematic research review I could derive a tailor-made scenario design for the development of explorative scenarios for the sanitation sector in the year 2050, which I present in journal article E3 "Scenarios for the sanitation sector in Germany: a Delphi-based approach" that is prepared for submission to the journal "Water Resources Research."

1.5.3.1 Journal Article E1: Sustainable Corporate Management by Means of the Delphi-technique

Nowack, Martin / Günther, Edeltraud, published in: Das Wirtschaftsstudium, Vol. 40 (2011), No. 4/11, p. 510-511.

In this article the Delphi-technique as instrument for a sustainable corporate management is presented and illustrated.

E1: Nachhaltige Unternehmensführung mit der Delphi-Methode*

Nowack, Martin / Günther, Edeltraud, erschienen in: Das Wirtschaftsstudium, Jg. 40 (2011), Heft 4/11, S. 510-511.

In diesem Artikel wird die Delphi-Methode zur Unterstützung einer nachhaltigen Unternehmensführung am Beispiel der Abwasserwirtschaft vorgestellt.

1.5.3.2 Journal Article E2: Review of Delphi-based Scenario Studies: Quality and Design Considerations*

Nowack, Martin / Endrikat, Jan / Günther, Edeltraud, published in: Technological Forecasting and Social Change (2011), article in press, corrected proof, doi:10.1016/j.techfore.2011.03.006.

For meaningful scenarios, creative input concerning possible future trends is crucial. Herman Kahn, the father of modern scenario planning, underlined the importance of "thinking the unthinkable" in a significant scenario study. "Blessed with high intelligence, an assertive personality and the research capabilities of the RAND Corporation," he could rely on genius forecasting. But how can this foresight be creative as well as simultaneously credible and objective if one does not possess Kahn's genius? In this article, we assess the incorporation of expert knowledge via the Delphi technique into scenario planning as a promising option. We discuss possible combinations and identify the span of design alternatives in the existing body of Delphi-based scenario studies through a systematic research review and provide recommendations on how a Delphi-based scenario study should be designed to ensure quality. We recommend focusing on the integration of the Delphi technique only in one phase of the scenario approach. In this way, the design options can be intentionally adjusted to the particular function. We further offer recommendations on how to accomplish this.

Review Delphi-basierter Szenariostudien: Qualitäts- und Designbetrachtungen

Nowack, Martin / Endrikat, Jan / Günther, Edeltraud, veröffentlicht in: Technological Forecasting and Social Change (2011), Artikel in Druck, korrigiert und angenommen, doi:10.1016/j.techfore.2011.03.006.

Für ausdrucksfähige Szenarien sind kreative Ideen zu möglichen zukünftigen Herausforderungen von entscheidender Bedeutung. Herman Kahn, der Vater der modernen Szenarioplanung, betonte wie wichtig es ist in solchen Szenarien „das Undenkbare zu denken". „Gesegnet mit einer hohen Intelligenz, einer durchsetzungsfähigen Persönlichkeit und den Ressourcen der RAND Corporation" konnte er auf sein Genie als maßgebliches Foresight-Instrument zurückgreifen. Aber wie kann ein Foresight-Prozess kreativ und gleichzeitig glaubwürdig und objektiv sein, wenn ein Zukunftsforscher nicht über Kahns Genie und Ressourcen verfügt? In diesem Artikel bewerten wir die Einbettung von Expertenwissen in die Szenarioplanung auf Basis der Delphi-Methode als eine vielversprechende Antwort auf diese Frage. Wir diskutieren verschiedene Kombinationsmöglichkeiten und zeigen auf Basis einer systematischen Literaturrecherche die in der Literatur verwendete Spannbreite möglicher Designalternativen auf. Wir leiten Empfehlungen ab, wie eine Delphi-basierte Szenariostudie gestaltet werden sollte, um ein hohes Maß an Qualität sicherzustellen. Wir empfehlen die Delphi-Technik primär in einer Stufe des Szenarioprozesses zu integrieren, um das Design besser auf die gewünschte Wirkung ausrichten zu können.

1.5.3.3 Journal Article E3: Scenarios for the Sanitation Sector in Germany: a Delphi-based Approach*

Nowack, Martin, prepared for Publication in: Water Resources Research.

The capital intensive and path-dependent sanitation sector is vulnerable to changing framework conditions, as the current experiences with decreasing populations in East Germany are proving. Therefore, alternative planning approaches are needed which allow decision-makers in the sanitation sector to prepare sufficiently early for future challenges. In this article I present the results of a scenario study on the future of the sanitation sector in the year 2050 in which I investigated the possibilities of scenario planning to overcome possible shortcomings of former planning approaches. The major contributions of my research are the identification of the most relevant future challenges and the development of a set of future scenarios which provide a valuable basis for strategy development in the sanitation sector.

Szenarien für den deutschen Abwassersektor: ein Delphi-basierter Ansatz

Nowack, Martin, zur Veröffentlichung vorgesehen in: Water Resources Research.

Die kapitalintensive und pfadabhängige Abwasserwirtschaft ist anfällig gegenüber sich ändernden Rahmenbedingungen, wie die aktuelle Erfahrung mit einer sinkenden Bevölkerung in Ostdeutschland zeigt. Aus diesem Grund werden alternative Planungsinstrumente benötigt, die die Entscheidungsträger in der Abwasserwirtschaft in die Lage versetzt, sich frühzeitig auf zukünftige Herausforderungen vorzubereiten. In diesem Artikel stelle ich die Ergebnisse einer Studie vor, in der verschiedene Szenarien für die Abwasserwirtschaft im Jahr 2050 erstellt werden. Es werden die Möglichkeiten der Szenarioplanung untersucht, wie die Mängel der herkömmlichen Planungsinstrumente überwunden werden können. Als wichtigstes Ergebnis dieser Forschung werden die relevantesten zukünftigen Herausforderungen identifiziert und in Szenarien zusammengefasst. Diese stellen eine wertvolle Ausgangsbasis für eine Strategieentwicklung in der Abwasserwirtschaft dar.

1.6 References

Beuhler, M. (2003), Potential impacts of global warming on water resources in southern California, *Water Sci. Technol., 47*(7-8), 165-168.

Bishop, P., A. Hines, and T. Collins (2007), The current state of scenario development: An overview of techniques, *Foresight, 9*(1), 5-25, doi: 10.1108/14636680710727516.

Börjeson, L., M. Höjer, K. Dreborg, T. Ekvall, and G. Finnveden (2006), Scenario types and techniques: Towards a user's guide, *Futures, 38*(7), 723-739, doi: 10.1016/j.futures.2005.12.002.

Bradfield, R., G. Wright, G. Burt, G. Cairns, and K. Van Der Heijden (2005), The origins and evolution of scenario techniques in long range business planning, *Futures, 37*(8), 795-812, doi: 10.1016/j.futures.2005.01.003.

Chermack, T. J., S. A. Lynham, and W. E. A. Ruona (2001), A Review of scenario planning literature, *Futures Res. Q., 17*(2), 7-31, doi: www.cse.buffalo.edu/~peter/refs/DataAssimilation/Multihypothesis/ReviewofSP.PDF.

Courtney, H. (2003), Decision-driven scenarios for assessing four levels of uncertainty, *Strategy & Leadership, 31*(1), 14-22, doi: 10.1108/10878570310455015.

Dominguez, D., and W. Gujer (2006), Evolution of a wastewater treatment plant challenges traditional design concepts, *Water Research, 40*(7), 1389-1396, doi: 10.1016/j.watres.2006.01.034.

Dominguez, D., B. Truffer, and W. Gujer (2006), Driving forces in the long range development of wastewater treatment plants, paper presented at iEMS Third Biennial Meeting, "Summit on Environmental Modelling and Software", International Environmental Modelling and Software Society, Burlington, USA.

European Parliament and European Council (2000), EU Water Framework Directive, *EC of the European Parliament and of the Council, 23/10/2000*.

Geschka, H. and R. Hammer (1997), Die Szenariotechnik in der strategischen Unternehmensplanung, in Strategische Unternehmungsplanung - Strategische Unternehmungsführung : Stand und Entwicklungstendenzen, 7. völlig neubearb. und erw. Aufl., edited by Dietger Hahn and Bernard Taylor of Mansfield, pp. 464-489, Physica-Verl., Heidelberg.

Godet, M. (2000), The Art of Scenarios and Strategic Planning: Tools and Pitfalls, *Technol. Forecast. Soc. Change, 65*(1), 3-22, doi: 10.1016/S0040-1625(99)00120-1.

Gordon, T. J. (1994), Trend impact analysis, *Futures Research Methodology*.

Hiessl, H. (2003), *Alternativen der kommunalen Wasserversorgung und Abwasserentsorgung, AKWA 2100*, Technik, Wirtschaft Und Politik, vol. 53, Physica-Verl., Heidelberg.

Hillenbrand, T., J. Niederste-Hollenberg, E. Menger-Krug, S. Klug, R. Holländer, S. Lautenschläger, S. Geyler, U. Winkler, S. Geisler, and T. Völkner (2010), Demographic change as a challenge to secure and develop cost- and resource-efficient wastewater infrastructur, *Texte, 36/2010*, 1-253, doi: www.umweltdaten.de/publikationen/fpdf-l/3779.pdf, Umweltbundesamt, Dessau-Roßlau.

Huss, W. R., and E. J. Honton (1987), Scenario Planning - What Style Should You Use?, *Long Range Plann., 20*(4), 21-29, doi: 10.1016/0024-6301(87)90152-X.

IPCC Working Group III (Ed.) (2000), *Special Report on Emissions Scenarios*, 612 pp., Cambridge University Press, New York.

Lempert, R., S. Hoorens, M. Hallworth, and T. Ling (2009), *Looking Back on Looking Forward: A Review on Evaluative Scenario Literature*, 28 pp., European Environment Agency, Copenhagen.

Malaska, P., M. Malmivirta, T. Meristo, and S. Hansen (1984), Scenarios in Europe - who uses them and why?, *Long Range Plann., 17*(5), 45-49, doi: 10.1016/0024-6301(84)90036-0.

Martelli, A. (2001), Scenario building and scenario planning: state of the art and prospects of evolution, *J. Futures Res. Q., 17*(3), 57-74.

Means, E., R. Patrick, L. Ospina, and N. West (2005), Scenario planning: A tool to manage future water utility uncertainty, *J. Am. Water Works Assoc., 97*(10), 68-75.

Mietzner, D. and G. Reger (2004), Paper 3 : Scenario Approaches – History, Differences, Advantages and Disadvantages.

Mietzner, D., and G. Reger (2005), Advantages and disadvantages of scenario approaches for strategic foresight, *Int. J. Technol. Intelligence and Plann., 1*(2), 220-239, doi: 10.1504/IJTIP.2005.006516.

Miller, K. D., and H. G. Waller (2003), Scenarios, Real Options and Integrated Risk Management, *Long Range Plann., 36*(1), 93-107, doi: 10.1016/S0024-6301(02)00205-4.

Nordlund, G. (2008), Futures research and the IPCC assessment study on the effects of climate change, *Futures, 40*(10), 873-876, doi: DOI: 10.1016/j.futures.2008.07.022.

Nowack, M. and E. Guenther (2009), Scenario planning: Managing the effects of demographic change on East German wastewater companies, paper presented at IHDP Open Meeting 2009, 7th International Science Conference on the Human Dimensions of Global Environmental Change, Bonn.

Nowack, M. and E. Guenther (2010), Scenario planning: Managing the effects of demographic change on East German wastewater companies, in H2O - Wasser: Ökonomie und Management einer Schlüsselressource, Sammelband zum Waterday am 25.-26.2.2010 in Berlin, Http://www.diw.de/documents/publikationen/73/diw_01.c.347808.de/wasser_oekonomie_management.Pdf, edited by Deutsches Institut für Wirtschaftsforschung (DIW), pp. 45-63, DIW, Berlin.

Nowack, M., J. Endrikat, and E. Guenther (2011), Review of Delphi-based scenario studies: Quality and design considerations, *Technol. Forecast. Soc. Change*, doi: 10.1016/j.techfore.2011.03.006, In Press, Corrected Proof.

Phelps, R., C. Chan, and S. C. Kapsalis (2001), Does scenario planning affect performance? Two exploratory studies*, J. Bus. Res., 51*(3), 223-232, doi: 10.1016/S0148-2963(99)00048-X.

Schnaars, S. P. (1987), How to develop and use scenarios*, Long Range Plann., 20*(1), 105-114, doi: 10.1016/0024-6301(87)90038-0.

Schnaars, S., and P. L. Ziamou (2001), The essentials of scenario writing*, Bus. Horiz., 44*(4), 25-31, doi: 10.1016/S0007-6813(01)80044-6.

Schoemaker, P. J. H. (1991), When and how to use scenario planning: A heuristic approach with illustration*, J. Forecast., 10*(6), 549-617, doi: 10.1002/for.3980100602.

Schoemaker, P. J. H. (1993), Multiple Scenario Development: its Conceptual and Behavioral Foundation*, Strategic Manage. J., 14*(3), 193-213, doi: 10.1002/smj.4250140304.

Schoemaker, P. J. H. (1995), Scenario Planning: A Tool for Strategic Thinking*, Sloan Manage. Rev., 36*(2), 25-40.

Schwartz, P. (1998)*, The Art of the Long View: Planning for the Future in an Uncertain World*, 258 pp., Wiley & Sons, Chichester.

Slaughter, R. A. (2002a), From forecasting and scenarios to social construction: changing methodological paradigms in futures studies*, Foresight, 4*(3), 26-31, doi: 10.1108/14636680210697731.

Slaughter, R. A. (2002b), Futures studies as a civilizational catalyst*, Futures, 34*(3-4), 349-363, doi: 10.1016/S0016-3287(01)00049-0.

van Notten, P. W. F., J. Rotmans, M. B. A. van Asselt, and D. S. Rothman (2003), An up-dated scenario typology*, Futures, 35*(5), 423-443, doi: 10.1016/S0016-3287(02)00090-3.

van Notten, P. W. F., A. M. Sleegers, and M. B. A. van Asselt (2005), The future shocks: On discontinuity and scenario development*, Technol. Forecast. Soc. Change., 72*(2), 175-194, doi: 10.1016/j.techfore.2003.12.003.

Varum, C. A., and C. Melo (2010), Directions in scenario planning literature – A review of the past decades*, Futures, 42*(4), 355-369, doi: 10.1016/j.futures.2009.11.021.

Wack, P. (1985), Scenarios: uncharted waters ahead*, Harv. Bus. Rev., 63*, 73-89.

2 Journal Article I1:

Szenarioplanung

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Titel:

Szenarioplanung

Published in:

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WISU-KOMPAKT

ÖKOLOGIE UND WIRTSCHAFT

Die Umweltgefährdung verlangt schnelle und nachhaltige Maßnahmen. Hier werden Instrumente vorgestellt, die zur Erhaltung der natürlichen Umwelt beitragen.

Szenarioplanung

*Energiekrisen, globalisierte Märkte und Deregulierung, aber auch der demografische Wandel und der Klimawandel stellen die Unternehmen vor neue Herausforderungen. Abb. 1 veranschaulicht diese Umfeldeinflüsse am Beispiel der Abwasserwirtschaft. Entscheidungsträgern in privaten Unternehmen und öffentlichen Einrichtungen stellt sich damit die Frage, wie die **Konsequenzen dieser Trends bewertet** und die **Risiken vermindert** werden sollen, und wie sich daraus eventuell ergebende Geschäftsmöglichkeiten wahrgenommen werden können.*

*Anhand historischer und aktueller Daten können zwar **Trends in die Zukunft** fortgeschrieben werden, **unvorhersehbare Ereignisse** (z.B. ein technologischer Durchbruch oder eine Wirtschaftskrise) lassen sich jedoch nur unvollkommen berücksichtigen. Stattdessen besteht die Gefahr, dass sie überhaupt nicht beachtet werden. So beruhten Planungen in der Siedlungswasserwirtschaft häufig auf historischen Daten, was dazu führte, dass wegen des demografischen Wandels und des deshalb zurückgehenden Wasserverbrauchs Überkapazitäten aufgebaut wurden.*

*Ein **alternatives Planungsinstrument** ist die Szenarioplanung. Dabei wird ein Bündel möglicher Entwicklungen entworfen, aus denen Konsequenzen für das heutige Handeln abgeleitet werden. Szenarien beschreiben also **mögliche Ausprägungen der Zukunft**.*

*Szenariomethoden wurden erstmals während des Kalten Krieges von **Herman Kahn** entwickelt, der für die Rand Cooperation arbeitete. Er gilt damit als Vater der modernen Szenarioplanung. Wenig später wendete Pierre Wack sie als einer der ersten in einem wirtschaftlichen Umfeld bei der Royal Dutch/ Shell Group an.*

*Da Praktiker und Forscher unterschiedlicher Disziplinen die Szenarioplanung genutzt und an ihre jeweiligen Bedürfnisse angepasst haben, ist ein **unsystematisches Nebeneinander** verschiedener **Methoden und Instrumente** entstanden. Die Anwender beziehen sich meist auf bestimmte Autoren wie etwa Schwartz oder Geschka/Hammer im deutschsprachigen Raum. Eine **systematische Entscheidungshilfe** oder Theorie, welche Methode für welche Aufgabe am sinnvollsten ist, ist bislang **nur in Ansätzen** erkennbar. Je nach Autor unterscheiden sich Definitionen, Techniken und sogar die Zahl der Schritte, die bei einem Szenarioprojekt erforderlich sind. So teilen Geschka/Hammer Szenarioprojekte in acht Schritte auf, andere arbeiten mit vier, während wieder andere bis zu zwölf Schritte vorschlagen. Hier wird der Ansatz von Bishop/Hines/Collins vorgestellt.*

Die Szenarioentwicklung

*Prinzipiell kann ein Szenarioprojekt in zwei Phasen unterteilt werden: In der **ersten Phase**, der Szenarioentwicklung, werden die eigentlichen Szenarien erstellt (Schritte 1 - 3).*

- *1. **Framing** — Systemgrenzen, Zweck, Ziel, Bearbeiter und Zielgruppe werden festgelegt. Das Ergebnis ist der Projektplan.*
- *2. **Scanning** — Historische und aktuelle Informationen sowie Prognosen und Trends werden gesammelt. Das ergibt die Datenbasis.*
- *3. **Forecasting** — Erstellung von Baseline- sowie alternativen Szenarien, Identifizierung der wichtigsten Treiber, Unsicherheiten und deren Auswirkungen.*

*Bei der Szenarioentwicklung kommt es vor allem darauf an, die **wichtigsten Treiber** zu identifizieren. Diese werden in sinnvollen Kombinationen in Szenarien zusammengefasst.*

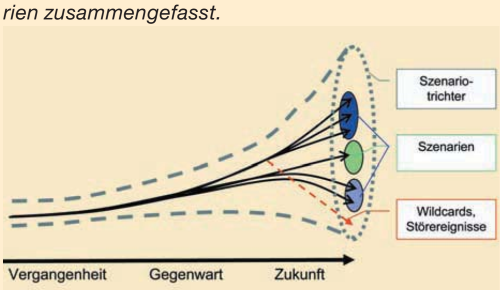

Abb. 2: Szenarioentwicklung

*Ein guter Ausgangspunkt ist ein **Baseline-Szenario** bzw. ein Business-as-usual-Szenario (BAU-Szenario). Das Szenario wird unter der Annahme erstellt,*

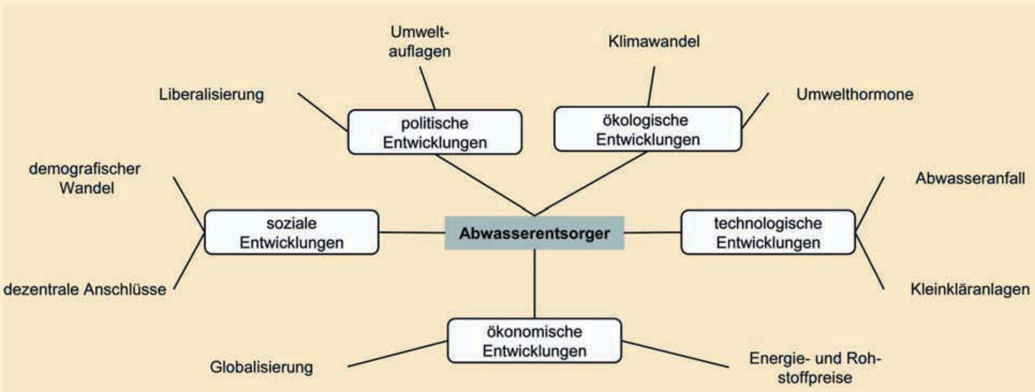

Abb. 1: Umfeldeinflüsse in der Abwasserwirtschaft

*dass sich alles so weiterentwickelt wie bisher. Ein Baseline-Szenario kann bereits ausreichen, um einem Unternehmen entsprechenden **Handlungsbedarf aufzuzeigen**. So lässt sich im Abwassersektor der Rückgang der Gebühren- und Beitragszahler gut aufgrund des demografischen Wandels prognostizieren.*

*Ohne weitere Szenarien reicht ein **Baseline-Szenario** für eine aussagekräftige Szenarioplanung allerdings **nicht** aus, da sonst möglicherweise entscheidende Entwicklungen vernachlässigt würden. Baseline-Szenarien beruhen auf Vergangenheitswerten und entsprechenden Hochrechnungen, wobei **Wildcards bzw. Störereignisse** ignoriert werden. Dies sind Entwicklungen, die sich nicht durch die Fortschreibung bisheriger Trends erkennen lassen. Dazu gehören z.B. technologische Durchbrüche oder Wirtschaftskrisen. Wildcards können dazu führen, dass sich die Zukunft völlig anders entwickelt. Durch sie kann sich der **mögliche Zukunftsraum** (Ende des Szenariotrichters) **erheblich** vergrößern.*

*Besonderes Augenmerk erfordern Entwicklungen mit sehr **geringer Eintrittswahrscheinlichkeit**, die jedoch **fatale Konsequenzen** nach sich ziehen würden. Im Abwasser-Beispiel wäre dies z.B. die Abkehr vom Anschlusszwang oder eine gesetzliche Verpflichtung, die Kläranlagen um eine dritte Reinigungsstufe zu ergänzen, damit auch Umwelthormone aus dem Abwasser entfernt werden können. Derartige **extreme Entwicklungen** sind die Grundlage für Extremszenarien wie dem **Worst-Case-Szenario**. Szenarien können z.B. als High-Tech-, Aufschwung-, Ökodiktatur- oder Depressionsszenario bezeichnet werden. Griffige Bezeichnungen wie diese helfen, kreative Antworten zu erarbeiten.*

Der Szenariotransfer

*In der **zweiten Phase** des Ansatzes von Bishop/Hines/Collins, dem Szenariotransfer, werden aus den verschiedenen Szenarien die jeweiligen Konsequenzen für das heutige Handeln gezogen (Schritte 4 - 6):*

- *4. **Visioning** — Durch die Wahl des bevorzugten Szenarios und die Identifizierung von Handlungserfordernissen entsteht eine Zukunftsvision.*
- *5. **Planning** — Die Auswahl strategischer Ziele führt zu einer Strategie.*
- *6. **Acting** — Jetzt werden die geplanten Maßnahmen umgesetzt.*

*Welche Konsequenzen ergeben sich für das Unternehmen, wenn z.B. das Aufschwungszenario eintritt? Wie kann sich das Unternehmen schon heute auf diese Situation vorbereiten? In der Spieltheorie wird dieses Vorgehen **„Lösung durch Rückwärtsinduktion“** genannt. Das Unternehmen konfrontiert sich mit verschiedenen Ausprägungen der Zukunft und entwirft entsprechende Gegenmaßnahmen und Strategien. Hier liegt die Herausforderung häufig darin, eingeschliffene Denkmuster und Vorgehensweisen zu überwinden und das kreative Potenzial des Unternehmens zu erschließen.*

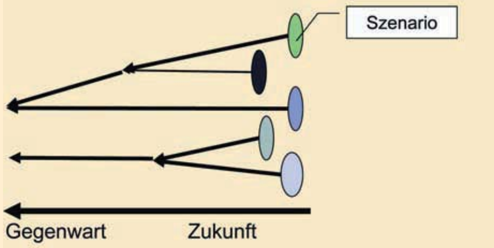

Abb. 4: Szenariotransfer

Beurteilung

*Ein **Nachteil der Szenarioplanung** ist, dass der Prozess kleineren und mittleren Unternehmen oft unbekannt ist, zudem ist er recht aufwändig. Durch das Hinzuziehen externen Sachverstands oder durch Szenarioworkshops mit mehreren Partnern, die auch von Verbänden organisiert werden können, lässt sich hier Abhilfe schaffen.*

*Auf der anderen Seite kann die Szenarioplanung die **strategische Planung im Unternehmen wesentlich erleichtern**. Szenarien reduzieren die Komplexität, erleichtern die Kommunikation, stoßen Lernprozesse in der Organisation an und erleichtern die interdisziplinäre Zusammenarbeit. Darüber hinaus unterstützt die Szenarioplanung das Risikomanagement bei der **Identifizierung von Risiken**.*

*Aktuelle Aufmerksamkeit erfuhr das Thema durch die **Klimaszenarien des Intergovernmental Panel on Climate Change IPCC**, das 2007 neben Al Gore mit dem Friedensnobelpreis ausgezeichnet wurde.*

*Prof. Dr. Edeltraut Günther/
Dipl.-Volksw. Martin Nowack, Dresden*

Literaturempfehlungen:

Bishop, P./Hines, A./Collins, T.: The Current State of Scenario Development: An Overview of Techniques. In: Foresight 9.1 (2007), S. 5 ff.
Fink, A./Schlake, O./Siebe, A.: Erfolg durch Szenario-Management: Prinzip und Werkzeuge der strategischen Vorausschau. Frankfurt a.M. 2001.
Geschka, H./Hammer, R.: Die Szenario-Technik in der strategischen Unternehmensplanung. In: Hahn, D./Taylor of Mansfield, B. (Hrsg.): Strategische Unternehmungsplanung — Strategische Unternehmungsführung: Stand und Entwicklungstendenzen. 7. Aufl., Heidelberg 1997, S. 464 ff.
Schwartz, P.: The Art of the Long View: Planning for the Future in an Uncertain World. Chichester et al. 1998.

	Szenarien		
Treiber	High-Tech	Aufschwung	Ökodiktatur
Energie- und Rohstoffpreise	ansteigend	stark ansteigend	sehr stark ansteigend
demografischer Wandel	Bevölkerungs-abnahme	leichte Bevölkerungs-zunahme	Bevölkerungs-abnahme
Umweltauflagen	streng	weniger streng	sehr streng
Abwasseranfall	leicht zurück-gehend	leicht zunehmend	stark zurück-gehend

Abb. 3: Beispiele aus der Abwasserwirtschaft

3 Journal Article I2:

Szenarioplanung im Integrierten Wasserressourcenmanagment

Authors:

Martin Nowack

Edeltraud Günther

Titel:

Szenarioplanung im Integrierten Wasserressourcenmanagement

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SCHWERPUNKTTHEMA

Szenarioplanung im integrierten Wasserressourcenmanagement

Martin Nowack · Edeltraud Günther


Edeltraud Günther


Martin Nowack

Zusammenfassung Klimawandel, demografischer Wandel, technologischer Wandel und deren Folgen, aber auch andere sich ändernde Rahmenbedingungen werden das integrierte Wasserressourcenmanagement (IWRM) in Zukunft vor große Herausforderungen stellen. Die Szenarioplanung erfasst zukünftige Entwicklungen und Trends und illustriert sie in Szenarien bzw. Zukunftsbildern mit dem Ziel, daraus die Konsequenzen für heutige Entscheidungen abzuleiten. Ziel dieses Artikels ist es daher, die Möglichkeiten der Szenarioplanung als integrierende Methode insbesondere im Hinblick auf das Wasserressourcenmanagement zu untersuchen.

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Die Methode der Szenarioplanung

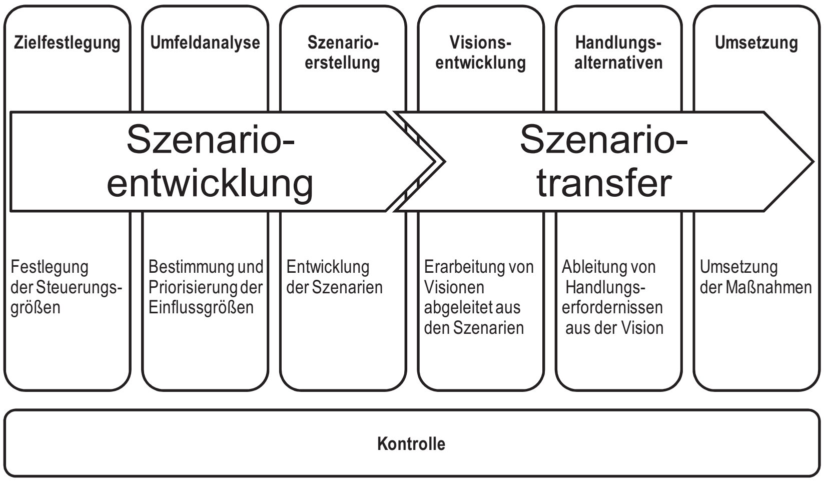
Zwei Zitate vermögen die Idee der Szenarioplanung gut auszudrücken:

1. „Es kommt nicht darauf an, die Zukunft vorherzusagen, sondern auf die Zukunft vorbereitet zu sein“ (Perikles, 493–429 v. Chr.) und
2. „If you do not think about the future, you cannot have one“ (Literaturnobelpreisträger John Galsworthy, 1928).

Genau diesen beiden Herausforderungen stellt sich die Szenarioplanung, indem sie einerseits auf zukünftige Entwicklungen vorbereitet (passive Funktion) und andererseits aber auch deren Gestaltung befördert (aktive Funktion). Die Szenarioplanung als Methode wurde maßgeblich während des Kalten Krieges in einem Spinn-off-Unternehmen der US Air Force der Rand Cooperation entwickelt.[1] Unter Leitung von Herman Kahn, der als Vater der modernen Szenarioplanung bezeichnet wird, wurden dort mögliche Szenarien für das Raketenabwehrsystem der USA entwickelt.[2] Pierre Wack wandte schließlich Kahns Methode zum ersten Mal im unternehmerischen Umfeld in der Ölindustrie bei der Royal Dutch Shell an. Nach einem ersten gescheiterten Versuch gelang es Wack, die Methode entsprechend weiterzuentwickeln, und er konnte so das Unternehmen auf die später eintretende Ölkrise vorbereiten (Wack 1985a,b).[3,4]

[1] Die Delphimethode wurde ebenfalls in der Rand Cooperation entwickelt.
[2] Als Ursprungsquelle kann hier auf Kahn & Wiener (1967) bzw. das weniger bekannte Werk von Kahn (1960) verwiesen werden.
[3] Zeitgleich wurden Szenarien auch bei General Electric angewandt, jedoch wurden diese Aktivitäten nicht so stark an die Öffentlichkeit getragen wie bei Royal Dutch Shell.
[4] Nähere Ausführungen zur geschichtlichen Entwicklung finden sich bei Bradfield, Wright, Burt, Cairns & van der Heijden (2005).

Abb. 1 Der Dresdner Szenarioansatz basierend auf Bishop et al. (2007)



Heute werden Szenariomethoden von Wissenschaftlern und Anwendern aus unterschiedlichen Disziplinen auf unterschiedlichste Art und Weise angewandt. Dementsprechend herrscht ein Nebeneinander von Definitionen und Methoden in diesem Forschungsfeld. Die Szenarioliteratur bemüht sich seit den 90er Jahren um eine Vereinheitlichung und Typologisierung. Nach wie vor kann jedoch von einem *„methodischen Chaos"*[5] gesprochen werden.[6]

Grundsätzlich wird ein Szenario als eine Beschreibung oder ein Abbild der Zukunft definiert.[7] Fink et al. (2001) beschreiben *„ein Szenario als eine von mehreren denkbaren Zukünften komplexer Systeme, die auf Verknüpfung einer Vielzahl denkbarer und konsistenter Einzelentwicklungen beruht."* Der übergeordnete Prozess der Szenarioplanung beschreibt den vollständigen Entscheidungsfindungsprozess, der auf Basis von Szenarien zukünftige Entwicklungen in die heutigen Entscheidungen integriert. Eine Szenarioplanung besteht grundsätzlich aus zwei Teilen: zum einen aus der Szenarioentwicklung und zum anderen aus dem Szenariotransfer. In der Szenarioentwicklung werden die eigentlichen Szenarien entworfen (passive Funktion), während in der Transferphase die Konsequenzen für die heute zu treffenden Entscheidungen abgeleitet werden (aktive Funktion). Einige Szenarioprojekte fokussieren auf den ersten bzw. auf den zweiten Teil. Die als Backcasting bezeichnete Methode legt den Schwerpunkt auf den zweiten Teil: Bei dieser speziellen Szenariotechnik konfrontiert man das Szenarioteam mit einem vorbereiteten Szenario und fragt explizit nach möglichen Konsequenzen für die heutige Entscheidung.[8,9] Die beiden Phasen werden je nach Autor in weitere Schritte untergliedert. Hier soll kurz der Dresdner Szenarioansatz dargestellt werden der auf Bishop et al. (2007) basiert.[10] Im ersten Schritt wird das Ziel des Szenarioprojektes festgelegt. In der Umfeldanalyse werden die Treiber und Einflussgrößen identifiziert und priorisiert. In der Szenarioentwicklung werden schließlich die Szenarien erstellt. Aus diesen werden anschließend mögliche Visionen abgeleitet, aus denen im nächsten Schritt Handlungserfordernisse deduziert werden. Im letzten Schritt werden die zu treffenden Maßnahmen umgesetzt. Während des gesamten Prozesses wird immer wieder kontrolliert, inwiefern die einzelnen Schritte und Entscheidungen mit dem Anfangs

[5] Den Ausdruck „methodisches Chaos" hat Martelli (2001) geprägt.

[6] Folgende Autoren bemühen sich um eine Typologisierung: Bishop et al. (2007), Bradfield et al. (2005), Börjeson, Höjer, Dreborg, Ekvall, & Finnveden (2006), Fink, Schlake, & Siebe (2001), Geschka & Hammer (1997), Mietzner & Reger (2004), Zürni (2004), van Notten, Rotmans, van Asselt, & Rothman (2003) und Voros (2006).

[7] Weitere Informationen zur Herkunft des Wortes Szenario finden sich bei Götze (1993), Meyer-Schönherr (1992) und bei von Reibnitz (1992).

[8] Backcastingexperiment: Stellen Sie sich vor, im New York des Jahres 2050 leben über 20 Mal so viele Einwohner wie heute. Diese müssen jedoch mit einer gleichbleibenden Trinkwassermenge auskommen. Welche Konsequenzen hätte dies für die Wasserversorgungstechnologien? Eventuell würden Sie bei diesem Gedankenspiel an geschlossene Wasserkreisläufe, eine 0,5-Liter Dusche, oder das 1.000 Liter Hochhaus als mögliche technische Antwortoptionen kommen. Diese kreativen Lösungen würden in einer auf der Vergangenheit bzw. aktuellen Entwicklungen basierenden Planung vermutlich zu spät oder gar nicht diskutiert.

[9] Unter Szenariotechnik sollen hier bestimmte Techniken verstanden werden, die den Szenarioplaner bei der Szenarioentwicklung oder beim Szenariotranfer unterstützen. Einen Überblick über verschiedene Szenariotechniken gibt Bishop, Hines, & Collins (2007).

[10] In der deutschen Betriebswirtschaftslehre wird häufig der Ansatz von Geschka & Hammer (1997) verwendet. Ein anschaulich dargestellter Szenarioansatz findet sich auch bei Gausemeier, Fink, & Schlake (1995). Eine Übersicht über die Vielzahl verschiedener Szenarioansätze geben Nowack & Guenther (2009).

definierten Ziel übereinstimmen oder ob Anpassungen notwendig sind.

Nachdem die Szenarioplanung kurz vorgestellt wurde, sollen nun die Anforderungen seitens des IWRM an die Szenarioplanung herausgearbeitet werden.

Das Integrierte Wasserressourcenmanagement

Als Leitkonzept der Wasserbewirtschaftung hat sich das integrierte Wasserressourcenmanagement als allgemein anerkanntes Prinzip in der Bewirtschaftung von Wasserressourcen durchgesetzt. Das IRWM wird vom Global Water Partnership (GWP) wie folgt definiert:

> *„IWRM stellt einen Prozess dar, der die koordinierte Entwicklung und Bewirtschaftung von Wasser, Land und damit verbundene Ressourcen fördert, um das sich daraus ergebende wirtschaftliche und soziale Gemeinwohl auf gerechte Weise zu maximieren, ohne dabei die Nachhaltigkeit der vitalen Ökosysteme zu gefährden." (GWP 2000)*

Zur Konkretisierung des IWRM wurden die vier Dublin-Prinzipien formuliert. Diese sind Ergebnis eines internationalen Verhandlungsprozesses auf UN-Ebene und wurden schließlich auf der Internationalen Konferenz für Wasser und Umwelt 1992 in Dublin verabschiedet. Anschließend wurden sie bei der Formulierung der Agenda 21 (Kapitel 18) auf dem UN-Gipfel in Rio berücksichtigt.

Die vier Dublin-Rio-Prinzipien sind:

1. Frischwasser ist eine endliche und vulnerable Ressource, die absolut notwendig ist für Leben, Entwicklung und die Umwelt.
2. Wasserbewirtschaftung und Planung sollten auf einem partizipativen Ansatz basieren, der Nutzer, Planer und Entscheidungsträger aller Ebenen einschließt.
3. Frauen spielen eine entscheidende Rolle bei der Verteilung, dem Management und dem Schutz von Wasser.
4. Wasser hat einen wirtschaftlichen Wert in allen seinen konkurrierenden Nutzungsarten und sollte als ökonomischen Gut betrachtet werden.

Aus der Konkretisierung der Dublin-Rio-Prinzipien der Global Water Partnership (2000, S. 14) können folgende Herausforderungen für das IWRM abgeleitet werden:

- Notwendigkeit einer aktiven **Partizipation** der Stakeholder, z. B. der Ober- und Unterlieger oder der verschiedenen Nutzergruppen.
- **Notwendigkeit einer Integration** verschiedenster Institutionen und Akteure mit unterschiedlichen Interessen, Zielen und aus unterschiedlichsten Disziplinen.
- **Notwendigkeit mit einem hohen Grad an Komplexität** umgehen zu können, z. B. verursacht durch den hohen Grad an Interdependenzen zwischen den natürlichen Ressourcen und der Komplexität des hydrologischen Systems an sich.
- Notwendigkeit einer **nachhaltigen Betrachtung**, die den wahren Wert des Wassers (inkl. externe Effekte) **und langfristige Änderungen** in den Rahmenbedingungen (z. B. Klimawandel und demografischer Wandel) berücksichtigt.[11]

Die Szenarioplanung bietet sich an, um als strategisches Planungsinstrument für das IWRM sowohl auf Organisations-, als auch auf Verbands-, Wassereinzugsgebiets- auf nationaler oder internationaler Ebene eingesetzt zu werden. Alcamo (2008) beschreibt u. a. folgende Funktionen von Szenarien, welche die Eignung der Szenarioplanung für das IWRM unterstreichen:[12]

- Szenarien können einerseits den zukünftigen Zustand der Umwelt beschreiben, wenn keine politischen Gegenmaßnahmen getroffen werden und so Handlungsbedarf aufzeigen (passive Funktion).
- Szenarien können andererseits alternative Pfade beschreiben und so die Effektivität von Politikmaßnahmen aufzeigen (aktive Funktion).

Dabei sind folgende Ausprägungen von besonderer Bedeutung:

- Szenarien können einen interdisziplinären Rahmen für die Analyse komplexer Umweltprobleme und Lösungen für die Probleme aufzeigen (Interdisziplinäre Integrationsfunktion).
- Szenarien können nützlich bei der Organisation, Darstellung und Kommunikation komplexer Informationen sein (Vereinfachungsfunktion).
- Szenarien können ein Bewusstsein für neue oder an Bedeutung zunehmende Umweltprobleme schaffen sowie für deren Interdependenz (Kommunikationsfunktion).
- Szenarien bieten Anspruchsgruppen eine Möglichkeit, sich aktiv zu beteiligen (Partizipationsfunktion).

Zur Bewältigung der Herausforderungen des IWRM können Szenarien einen wichtigen Beitrag leisten. Denn sie sind darauf ausgerichtet, mit einen hohen Grad an Komplexität umzugehen und diesen entsprechend für alle Anspruchsgruppen verständlich darzustellen. So erleichtern sie die Ziele der Partizipation und Integration im IWRM. Des Weiteren können Szenarien eine nachhaltige und langfristige Betrachtungsweise der Probleme im IWRM ermöglichen. Die Möglichkeiten der Szenarioplanung im IWRM werden in Tabelle 1 zusammenfassend dargestellt.

Die Möglichkeiten der Szenarioplanung für das IWRM werden auch deutlich, wenn die bereits durchgeführten Sze-

[11] Abgeleitet aus den Veröffentlichungen von UN-Water & Global Water Partnership (2007) und Global Water Partnership Technical Committee (TEC) (2009).

[12] Weitere Funktionen beschreibt Wiek, Binder & Scholz (2006).

Tabelle 1 Die Funktionen der Szenarioplanung im Wasserbereich

Herausforderungen des IWRM	Möglichkeiten der Szenarioplanung
Partizipation	• Szenarien erleichtern die Integration verschiedenster Sichtweisen und Meinungen. Je mehr Aspekte bei der Szenarioentwicklung einfließen, desto wertvoller werden die Szenarien. • Durch die Reduzierung der Komplexität können komplexe Sachverhalte leichter an die Anspruchsgruppen weitervermittelt werden.
Integration	• Szenarien ermöglichen die Zusammenarbeit über Fachgrenzen hinweg. • Szenarien können bei der Ausbildung eines gemeinsamen Mind Models hilfreich sein.
Komplexität	• Szenarien können sehr komplexe Sachverhalte einfach darstellen und erleichtern auf diese Weise, die richtige Entscheidung zu treffen.
Langfristigkeit	• Durch die Beschreibung der Zukunft können z. B. externe Effekte verdeutlicht werden (passive Funktion), • sowie die Lösungsoptionen aufgezeigt werden (aktive Funktion).

Tabelle 2 Szenariostudien im Wasserbereich

Name der Studie	Jahr	Herausgeber	Ziel	Bedeutung des Wassers
World Water Vision	2000	World Commission on Water	Ziel der World Water Vision Studie ist es, auf Basis eines partizipativen Prozesses den Zustand der weltweiten Wasserressourcen zu diagnostizieren und deren Bedrohung aufzuzeigen sowie daraus entsprechende Handlungsempfehlungen abzuleiten.	Wasser als bedrohte Ressource
World water and food to 2025	2001	International Food Policy Research Institute	An Hand der Darstellung verschiedener Politikansätze wollen die Verfasser der Studie die Interdependenzen der Ressource Wasser und einer sicheren Nahrungsmittelversorgung aufzeigen.	Wasser als determinierende Ressource für die Nahrungsmittelsicherheit
Millennium Ecosystem Assessment Scenarios: findings of the Scenarios	2005	Millennium Ecosystem Assessment	Das Millennium Ecosystem Assessment wurde durchgeführt, um die Konsequenzen der Veränderungen der Ökosysteme zu bewerten und deren Folgen für die Menschen aufzuzeigen sowie die wissenschaftliche Grundlage für die Ableitung entsprechender Gegenmaßnahmen zu schaffen.	Wasser als ein gefährdeter Lebensraum unter mehreren
Global International Waters Assessment (GIWA)	2006	United Nations Environmental Programme	Ziel von GIWA ist es, eine systematische und verständliche globale Bewertung internationaler grenzüberschreitender Gewässer zu schaffen, die es ermöglicht, eine entsprechende Strategie für die Global Environmental Facility (GEF) und andere Institutionen abzuleiten.	Wasser als Konfliktfaktor und gefährdete Ressource
Business in the World of Water-WBCSD water Scenarios to 2025	2006	World Business Council for Sustainable Development	Ziel der Szenariostudie ist es, die wichtigsten Herausforderungen und Einflussfaktoren im Zusammenhang mit der Wasserproblematik verständlich für die Teilnehmer aufzuarbeiten, ein zwischen den Unternehmern und Stakholdern gemeinsames Verständnis zur Problematik zu entwicklen und effektive Businesslösungen zu unterstützen.	Wasserproblematik als bedeutender Herausforderung für die Wirtschaft
Water for Food, Water for Life	2007	International Water Management Institute	Ziel der Studie ist es, notwendige Handlungsoptionen im Hinblick auf ein effizientes Wassermanagement in der Landwirtschaft zur sicheren Nahrungsmittelversorgung aufzuzeigen.	Wasser als elementare Ressource in der Landwirtschaft
Global environment outlook 4	2007	United Nations Environmental Programme	Der Global Environment Outlook 4 bewertet die Änderungen der Umweltmedien Atmosphäre, Land, Wasser und der Biodiversität und stellt die Konsequenzen für die menschliche Entwicklung dar.	Wasser als essenzielle Ressource für die Entwicklung
Environmental Outlook to 2030	2008	Organisation for Economic Cooperation and Development	Ziel des Environmental Outlook 2030 ist, darzustellen wie ökonomische und soziale Entwicklungen Einfluss auf die Umwelt nehmen und welche politischen Maßnahmen notwendig sind, diesen Herausforderungen entgegenzutreten.	Wasserknappheit als ein Kernproblem neben Klimawandel, Biodiversität und den Gesundheitsfolgen der Umweltverschmutzung
Water Scenarios for Europe and for Neighbouring States (SCENES)	Start 2006	Europäische Union 6. Forschungsrahmenprogramm	Das SCENES-Projekt will verständliche Szenarien zum Zustand der Frischwasserressourcen Europas und angrenzender Regionen im Jahr 2025 entwickeln und damit als strategische Entscheidungsgrundlage dienen.	Wasserproblematik als bedeutender Herausforderung für die Europäische Gemeinschaft

narioprojekte im Wasserbereich betrachtet werden. In Tabelle 2 sind die bedeutendsten Szenariostudien im globalen Wasserbereich dargestellt.[13]

Die Kommunikations- und Vereinfachungsfunktion wird besonders gut deutlich anhand der Szenariostudie des World Business Council for Sustainable Development (WBCSD). Ziel der Szenariostudie des WBCSD ist es, den Teilnehmern der Szenarioworkshops die wichtigsten Herausforderungen im Wasserbereich verständlich zu machen, damit diese gemeinsam mit den teilnehmenden Anspruchsgruppen ein gemeinsames Problembewusstsein schaffen und entsprechende Lösungen entwickeln können. Die in Tabelle 2 aufgelisteten globalen Studien integrieren sowohl die passive als auch die aktive Funktion. Insbesondere in der World Water Vision Szenariostudie werden sowohl die Herausforderungen deutlich herausgearbeitet als auch mögliche Handlungsoptionen aufgezeigt. Die Vereinfachungs- und Integrationsfunktion bekommt insbesondere bei Studien eine besondere Bedeutung, an denen mehrere Tausend Personen beteiligt waren, wie zum Beispiel am Millennium Ecosystem Assessment.

Wie aus den vorangegangenen Überlegungen deutlich wird, ist die Szenarioplanung als strategisches Planungsinstrument für das IWRM sehr gut geeignet. Dabei ist zu unterstreichen, dass dies nicht nur für die globale Ebene gilt, sondern auch für die Ebene des Wassereinzugsgebietes oder für die betriebliche Ebene. Auf diesen Ebenen können globale oder nationale Studien in Form einer Szenariokaskade integriert werden. Dies muss jedoch in Hinblick auf die zur Verfügung stehenden Ressourcen genau geplant werden. Je weniger Ressourcen zur Verfügung stehen und je kleiner der Bezugsrahmen wird, desto bedeutender werden die weicheren Funktionen der Szenarien wie die Kommunikationsfunktion. Komplexe Modellrechnungen sind dahingegen auf dieser Ebene nicht notwendig. Grundsätzlich besteht die Herausforderung darin, aus der Vielzahl an möglichen Szenariotechniken die geeigneten und in der jeweils richtigen Kombination auszuwählen. Angesichts der enormen Herausforderungen, die in Zukunft auf das IWRM zukommen, ist es unbedingt notwendig, verstärkt den Blick in die Zukunft zu wagen. Die Szenarioplanung bietet dazu einen vielversprechenden Rahmen.

Literatur

Alcamo J (Ed) (2008) *Environmental futures: The practice of environmental scenario analysis* (1.th ed.). Amsterdam, Boston, Heidelberg, London, New York, Elsevier

Bishop P, Hines A, Collins T (2007) The current state of scenario development: An overview of techniques. Foresight 9(1):5–25

Börjeson L, Höjer M, Dreborg K, Ekvall T, Finnveden G (2006) Scenario types and techniques: Towards a user's guide. Futures 38(7):723–739

[13] Einen Überblick über Szenariostudien auf Organisationsebene im Wasser und Abwasserbereich geben Nowack & Guenther (2009).

Bradfield R, Wright G, Burt G, Cairns G, Van Der Heijden K (2005) The origins and evolution of scenario techniques in long range business planning. Futures 37(8):795–812. doi:10.1016/j.futures.2005.01.003

Fink A, Schlake O, Siebe A (2001) *Erfolg durch Szenario-Management: Prinzip und Werkzeuge der strategischen Vorausscha*u. Frankfurt/Main u. a.: Campus-Verl.

Gausemeier J, Fink A, Schlake O (1995) *Szenario-Management. Planen und Führen mit Szenarien*. München: Hanser

Geschka H, Hammer R (1997) Die Szenario-Technik in der strategischen Unternehmensplanung. In: Hahn D, Taylor of Mansfield B (Eds) *Strategische Unternehmungsplanung – strategische Unternehmungsführung: Stand und Entwicklungstendenze*n (7, völlig neubearb. und erw. Aufl. ed., S. 464–489). Heidelberg: Physica-Verl

Global Water Partnership (Hrsg) (2000) *Integrated water resources management*

Global Water Partnership Technical Committee (TEC) (Ed) (2009) *Water management, water security and climate change adaptation: Early impacts and essential response*s, online verfügbar unter: http://www.gwpforum.org/gwp/library/GWP_TEC_14_FINAL.pdf

Götze U (1993) *Szenario-Technik in der Strategischen Unternehmensplanun*g (2., aktualisierte Aufl. ed.). Wiesbaden

Günther E (2008) *Ökologieorientiertes Management*. Stuttgart: Lucius & Lucius, UTB

Kahn H (1960) *On thermonuclear wa*r. Princeton, NJ u. a.: Princeton Univ. Pr

Kahn H, Wiener AJ (1967) *The year 2000: A framework for speculation on the next thirty-three year*s. New York: Macmillan u. a.

Meyer-Schönherr M (1992) *Szenario-Technik als Instrument der strategischen Planun*g. Ludwigsburg u. a.: Verl. Wiss. & Praxis

Mietzner D, Reger G (2004) *Paper 3: Scenario approaches – history, differences, advantages and disadvantages*

Martelli A (2001) Scenario building and scenario planning: state of the art and prospects of evolution. Journal of Futures Research Quarterly 17(3):57–74

Nowack M, Guenther E (2009) Scenario planning: Managing the effects of demographic change on East German wastewater companies, Conference Proceeding of the 7th International Science Conference on the Human Dimensions of Global Environmental Change „The Social Challenges of Global Change" 26.–30. April 2009 in Bonn, online verfügbar unter: http://www.openmeeting2009.org/pdf_files/Pdf%20papers/Nowack%20Guenther.pdf

Ulbrich Zürni S (2004) *Möglichkeiten und Grenzen der Szenarioanalyse eine Analyse am Beispiel der Schweizer Energieplanun*g. Stuttgart; Berlin

UN-Water & Global Water Partnership (Eds) (2007) *Roadmapping for advancing integrated water ressource managemen*t, online verfügbar unter: http://www.unwater.org/downloads/UNW_ROADMAPPING_IWRM.pdf

van Notten PWF, Rotmans J, van Asselt MBA, Rothman DS (2003) An updated scenario typology. Futures 35(5):423–443

von Reibnitz U (1992) *Szenario-Technik: Instrumente für die unternehmerische und persönliche Erfolgsplanun*g (2. Aufl ed.). Wiesbaden: Gabler

Voros J (2006) Introducing a classification framework for prospective methods. Foresight 8(2):43–56. doi:10.1108/14636680610656174

Wack P (1985a) Scenarios: Shooting the rapids. Harvard Business Review 63(6):139–150

Wack P (1985b) Scenarios: Uncharted waters ahead. Harvard Business Review 63(5):73–89

Wiek A, Binder C, Scholz RW (2006) Functions of scenarios in transition processes. Futures 38(7):740–766. doi:10.1016/j.futures.2005.12.003

4 Journal Article P1: Der demografische Wandel als Gebührentreiber in der Siedlungsentwässerung

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Titel:

Der demografische Wandel als Gebührentreiber in der Siedlungsentwässerung - Ein Vergleich des Demografieeffektes mit Spar-, Betriebskosten-, Kapitalkosten- und Industrieeffekten

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Der demografische Wandel als Gebührentreiber in der Siedlungsentwässerung

Ein Vergleich des Demografieeffektes mit Spar-, Betriebskosten-, Kapitalkosten- und Industrieffekten

Abwasserbehandlung, Demografischer Wandel, Gebühr, Prognose, Fixkosten

Martin Nowack, Sebastian John, Jens Tränckner und Edeltraud Günther

Der demografische Wandel in Form einer sinkenden Bevölkerungszahl (Demografieeffekt) und eines rückläufigen Abwasseranfalls (Spareffekt) stellt die Abwasserentsorger, neben technischen Aspekten, auch vor eine wirtschaftliche Herausforderung. Die langlebige und kapitalintensive Infrastruktur kann nur in begrenztem Maße an den demografischen Wandel angepasst werden. Der hohe Fixkostenanteil von 75–85 %, der auf weniger Einwohner umgelegt werden muss, droht die Gebühren entsprechend zu erhöhen. Dieser Beitrag untersucht anhand von drei Fallstudien, wie stark die Abwasserentsorger vom demografischen Wandel betroffen sind und wie sich die Gebührenbelastung der Haushalte aufgrund des demografischen Wandels zu erhöhen droht. Neben der Untersuchung der rückläufigen Bevölkerungsanzahl (Demografieeffekt) werden die Auswirkungen eines rückläufigen häuslichen Schmutzwasseranfalls (Spareffekt) und Veränderungen des industriellen Schmutzwasseranfalls (Industrieeffekt) sowie die Entwicklung der Betriebs- und Kapitalkosten miteinander verglichen, um die wesentlichen Gebührentreiber zu identifizieren.

Demographic Change as Driver of Wastewater fees in Urban Drainage Systems – A Comparison of Demography, Water Saving, Maintenance Cost, Operating Cost and Industry Effects

Decision makers in the wastewater industry face demographic changes in terms of a decreasing population and a declining quantity of wastewater. This results in technical hurdles and economic challenges. The economic challenges are caused by the durable and capital intensive infrastructure that can only be adapted in a very limited extent to the changing environment. The fixed costs add up to 75–85 % of the total costs and they have to be covered by a reduced number of feepayers, causing an increase of the wastewater fees per capita. This article analyses three case studies for the following questions: How strong a wastewater company is affected by demographic change? How will their wastewater fees increase due to demographic change? The article analyses beside the decreasing number of inhabitants (demographic effect), the impacts of decreasing water demand of the households (water saving effect) and of the industry (industry effect) as well as the development of the future operational expenditures (opex effect) and of the capital expenditures (capex effect) in order to compare the different effects and to identify the decisive fee drivers.

1. Einführung

1.1 Hintergrund

Die jüngste 12. koordinierte Bevölkerungsvorausberechnung des Statistischen Bundesamtes rechnet mit einem Bevölkerungsrückgang in Deutschland von etwa 82 Millionen Einwohnern am Ende des Jahres 2008 auf etwa 65 Millionen (Untergrenze der „mittleren“ Bevölkerung) beziehungsweise 70 Millionen (Obergrenze der „mittleren“ Bevölkerung) im Jahr 2060. Im Vergleich zum Jahr 2008 entspricht dies einem Rückgang von 21 % bzw. 15 % [1].

Insbesondere die ostdeutschen Bundesländer hatten bereits seit den 1990er Jahren einen deutlichen Bevölkerungsrückgang zu verkraften (siehe **Bild 1**). Ursache hierfür ist neben einem deutlichen Geburtendefizit die seit den 1990er Jahren in den neuen Bundesländern besonders ausgeprägte Binnenwanderung gen Westen. In Westdeutschland konnte das Geburtendefizit bis dato durch entsprechende Wanderungsgewinne ausgeglichen werden. Bis zum Jahr 2020 wird der Osten laut Prognosen bis auf wenige Wachstumskerne weiter schrumpfen, ebenso wie einige strukturschwache Regionen in Westdeutschland (siehe **Bild 2**) [2].

Der Bevölkerungsrückgang hat Auswirkungen auf die verschiedenen Bereiche der Infrastruktur. Im Abwasserbereich wird der Rückgang des Abwasseranfalls durch die verringerte Bevölkerungszahl (demografischer Effekt) durch einen stark rückläufigen Pro-Kopf-Wasserverbrauch (Spareffekt) verstärkt. In der Vergangenheit hat der spezifische Wasserverbrauch bereits stark abgenommen. Während im Jahr 1987 in Westdeutschland je Einwohner und Tag 146 Liter Wasser verbraucht wurden, sank dieser Wert für die gesamte Bundesrepublik seit der Wende kontinuierlich von 144 Liter (1990) auf 122 Liter im Jahr 2007. Wiederum ist diese Entwicklung in Ostdeutschland besonders stark ausgeprägt. Im Jahr 2007 lag die Wasserabgabe an Haushalte und Kleingewerbe in den ostdeutschen Bundesländern (inkl. Berlin) im Schnitt bei 96 Liter je Einwohner und Tag. In Westdeutschland hingegen werden im gleichen Jahr im Durchschnitt 30 Liter Wasser mehr pro Tag und Kopf als in Ostdeutschland verbraucht. Ganz besonders gering ist der sächsische Wasserverbrauch mit 85 Litern pro Tag[1] [1]. Prognosen gehen von einem weiteren Rückgang des Wasserverbrauchs aus.

Die Abwasserbetriebe stehen darüber hinaus auch vor der Herausforderung, dem zu erwartenden Sanierungsbedarf gerecht zu werden. Die Ergebnisse der ATV-DVWK-Umfrage 2004[2] ergaben, dass zum Zeitpunkt der Studie rund 20 % der 486 000 Kanalkilometer kurz- bis mittelfristig sanierungsbedürftig sind [3]. Laut DWA [4] wurden 2009 etwa 4,6 Milliarden Euro in der Abwassersparte investiert. Darunter fallen jedoch auch die Investitionen in Kläranlagen und Neubau. *Wolf* u. a. [5] rechnen vor, dass bei schätzungsweise 1,64 Mrd. Euro jährlichen kanalspezifischen Sanierungsinvestitionen die Kanäle ein Alter von 400 Jahren erreichen müssten. Trotz der Bemühungen nach der Wende, die Infrastruktur in Ostdeutschland in Stand zu setzen, ist der Anteil des Kanalnetzes, der vor 1980 gebaut wurde, in den meisten ostdeutschen Bundesländern sowie

[1] Eine mögliche Ursache hierfür ist der Preisschock nach der Wende. Viele Ostdeutsche zahlten bis zur Wende nur sehr geringe Wassergebühren von rund 10 Pfennig pro Kubikmeter und verbrauchten bis zu 300 Liter pro Einwohner und Tag [6]. Die Instandsetzung der ostdeutschen Abwasserinfrastruktur ließ die Abwassergebühren im Vergleich zu DDR-Zeiten stark ansteigen. In den 1990er Jahren waren die Ostdeutschen entsprechend sehr preissensibel und nutzten die Möglichkeit im Haushaltsbereich, Renovierungen durchzuführen, die bis dato nicht möglich waren, z. B. der Einbau von Wasser sparenden Sanitäreinrichtungen und der Neukauf weißer Ware. *Schleich* [7] arbeitet als Hauptgründe für den deutlichen Ost-West-Unterschied den in Ostdeutschland höheren Wasserpreis sowie das geringere Pro-Kopf-Einkommen heraus.

[2] Die Umfrage zum Zustand der Kanalisation wird zurzeit durch den DWA wiederholt. Die bisherigen Ergebnisse sind von *Berger* [3] veröffentlicht worden.

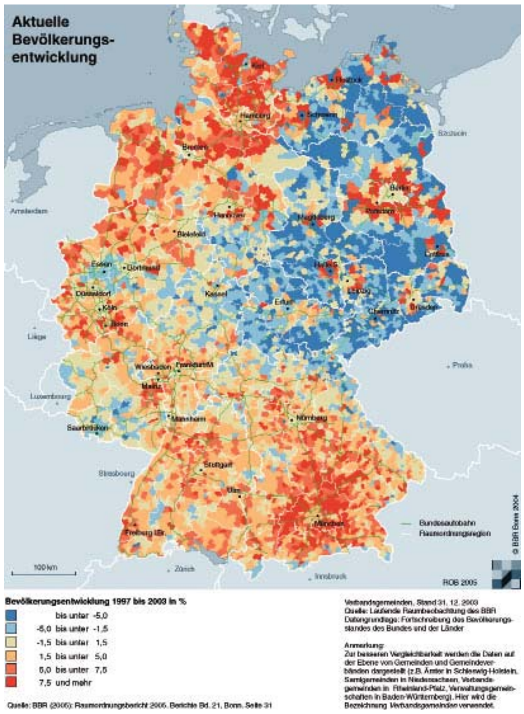

***Bild 1**. Aktuelle Bevölkerungsentwicklung.*

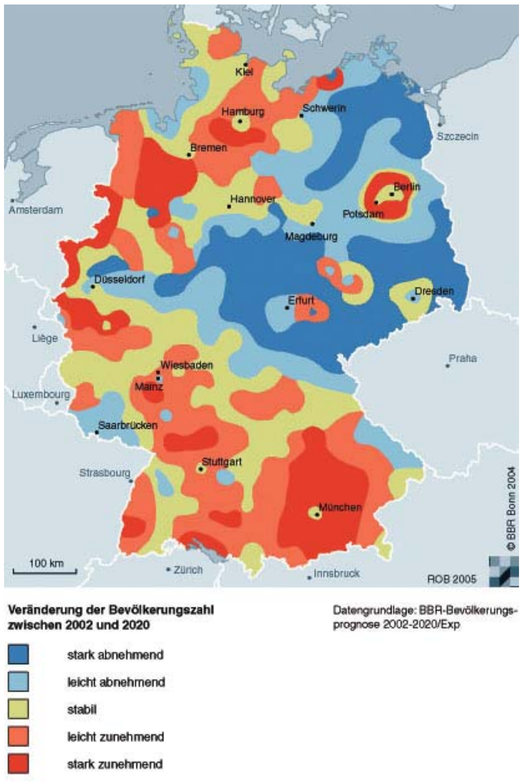

***Bild 2**. Trend der Bevölkerungsentwicklung bis 2020.*

Hessen und Hamburg immer noch vergleichsweise hoch. Das bedeutet, dass in Ostdeutschland neben dem demografischen Wandel auch mit zunehmendem Sanierungsbedarf und damit auch mit steigenden Kapitalkosten[3] zu rechnen ist.

1.2 Stand des Wissens

Die langlebige und kapitalintensive Infrastruktur der Siedlungsentwässerung (Kanäle 40–80 Jahre, Kläranlagen 20–35 Jahre) hindert die Abwasserbetriebe daran, die bestehenden Systeme an die sich ändernden Rahmenbedingungen anzupassen. Die hohen Infrastrukturkosten werden über deren gesamte zu erwartende Nutzungsdauer in Form von Abschreibungen periodisiert. Die Abschreibungen sind entsprechend über einen langen Zeitraum festgeschrieben und, ebenso wie die kalkulatorischen Zinsen, unabhängig von der Menge des gereinigten Abwassers oder der Anzahl der versorgten Einwohner. Zu diesen Fixkosten können neben den kalkulatorischen Kosten je nach Interpretation auch weitere Kosten, wie z. B. die Personalkosten gezählt werden. Die Fixkosten betragen in der Abwasserentsorgung im Durchschnitt 75 bis 85 % der gesamten Kosten. Dementsprechend droht bei einem Bevölkerungsrückgang ein entsprechender Gebührenanstieg, da annähernd gleich bleibende Kosten auf weniger Nutzer und entsprechend geringere Abwassermengen umgelegt werden müssen [8].

Die Auswirkungen des demografischen Wandels auf die Abwassergebühren werden in einzelnen Veröffentlichungen bereits modellhaft analysiert [9–13]. Bei diesen Modellrechnungen werden zum Teil nur die nötigsten Parameter für die Prognose der Gebühren in Abhängigkeit vom demografischen Wandel berücksichtigt, wie z. B. der Bevölkerungsrückgang, der Anteil der Fixkosten und die entsprechende Gebühr pro Kubikmeter.

Einige Autoren sprechen im Zusammenhang mit dem demografischen Wandel bereits von einem demografiebedingten Teufelskreis [14, 15]. Gemeint ist hiermit ein sich verstärkender Effekt aus einem Rückgang der Einnahmen, einem Anstieg der Betriebskosten und einer sinkenden Wassernachfrage aufgrund der zuvor gestiegenen Gebühren. *Lux* [11] und *Seitz* [16] rücken die Bedeutung des hohen Fixkostenanteils in den Vordergrund und sprechen von der Fixkostenfalle bzw. von Kostenremanenz. Die Auswirkungen des rückläufigen Wasserbedarfs bzw. die Berücksichtigung des demografischen Wandels in der Wasserbedarfsprognose wurden zum Teil bereits diskutiert [17–23]. *Wangenheim* u. a. [24] stellen ein erstes Gebührenprognoseverfahren vor, das auf das optimale Verhältnis von Gebühren und Beiträgen fokussiert, gehen jedoch nicht auf den demografischen Wandel als Gebührentreiber ein. Die Berücksichtigung des demografischen Wandels, eines rückgängigen Abwasseranfalls und die gleichzeitige Verbindung mit einer Prognose der Betriebs- und Kapitalkosten sind methodisch neu.

1.3 Ziel der Arbeit

Ziel des Beitrags ist, die Auswirkungen des demografischen Wandels als Treiber der Gebührenbelastung der Haushalte zu analysieren und von anderen Gebührentreibern zu differenzieren und mit diesen zu vergleichen. Als weitere Gebührentreiber werden der rückläufige häusliche Abwasseranfall (Spareffekt), eine Veränderung des industriellen Schmutzwasseranfalls (Industrieeffekt) sowie Änderungen der Betriebs- (Betriebskosteneffekt) und Kapitalkosten (Kapitalkosteneffekt) untersucht.. Dazu wurde ein Gebührenprognoseverfahren entwickelt, das eine Gebührenprognose für einen Zeitraum von 10 bis 15 Jahren ermöglicht. Das Gebührenprognoseverfahren wurde in drei Fallstudien in Gladbeck, Bautzen und beim Abwasserzweckverband (AZV) Spreequellen getestet.

Aus Betreibersicht stellen sich die folgenden drei Forschungsfragen:

1. Um wie viel Prozent steigen die Abwassergebühren bis zum Jahr 2020 insgesamt?
2. Welchen Anteil haben der demografische Wandel bzw. andere Effekte an der Gebührenerhöhung?
3. Wie sensibel reagiert die Gebührenbelastung der Haushalte, wenn der demografische Wandel (oder andere Annahmen) stärker oder schwächer eintreten als angenommen?

2. Methoden und Vorgehensweise

Die drei Forschungsfragen wurden mithilfe des entwickelten Gebührenprognoseverfahrens für die drei Betreiber beantwortet. Die Ergebnisse aus den drei Fallstudien werden in diesem Artikel vorgestellt. Die Analyse besteht aus drei Schritten.

Die Beantwortung der ersten Forschungsfrage „Um wie viel Prozent steigen die Abwassergebühren bis zum Jahr 2020 insgesamt?" ist Ziel der Bruttoprognose. In diesem ersten Analyseschritt ist eine möglichst realistische Prognose der Abwassergebührenbelastung der Haushalte des Jahres 2020 zu erstellen. Dazu werden in der Bruttoprognose die Ausgangsdaten gemeinsam mit dem Abwasserentsorger in ein Datenerfassungsblatt eingetragen und entsprechend individuelle Annahmen zu den zukünftigen Entwicklungen der einzelnen Parameter getroffen. Als Eingangsparameter werden neben den demografischen Daten sowohl der häusliche als auch der industrielle Schmutzwasseranfall sowie die Betriebs- und Kapitalkosten und das Gebührenerhebungsverfahren berücksichtigt.

[3] Unter Kapitalkosten wird hier der in der Wasserwirtschaft übliche Begriff für die Zusammenfassung von kalkulatorischen Abschreibungen und kalkulatorischen Zinsen synonym zu Investitionskosten verwendet. Vergleiche auch Merkblatt ATV-DVWK-M 803 Kostenstrukturen in der Abwassertechnik.

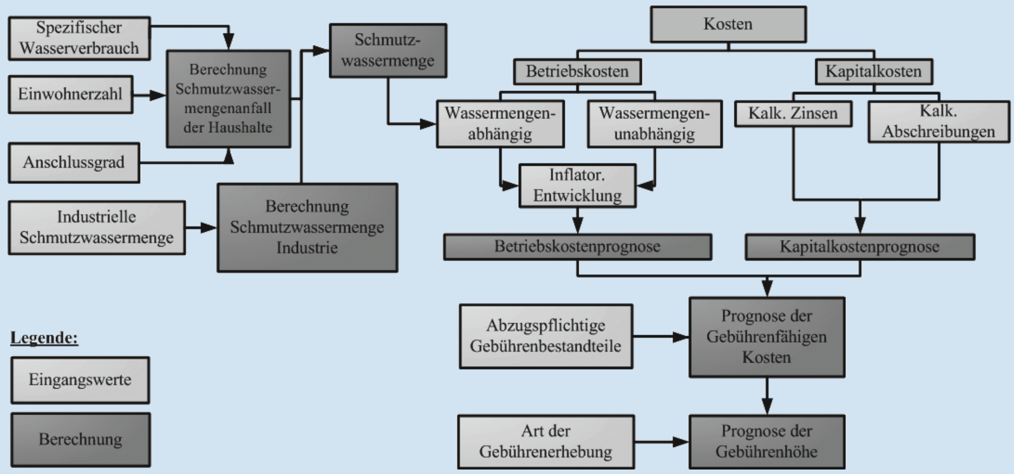

Bild 3. *Übersicht Gebühren-prognose.*

Für die Bevölkerungsprognosen werden Daten der Bertelsmann-Stiftung, der statistischen Ämter oder individuelle Bevölkerungsprognosen der jeweiligen Städte bzw. Betreiber verwendet. Der industrielle und häusliche Schmutzwasseranfall ergibt sich aus den Jahresverbrauchsabrechnungen. Die Betriebskosten werden mithilfe der jeweiligen Betreiber in das Datenerfassungsblatt eingetragen. Hierbei wird die zukünftige Kostenentwicklung für jede Kostenart (z.B. Materialien, Personal, Energie, Leistungen Dritter, Abwasserabgabe, Reststoffentsorgung) individuell auf Basis der Erfahrungswerte der Betreiber prognostiziert. Die Analyse basiert dabei auf noch detaillierteren Angaben zu den einzelnen Kostenarten, diese können hier jedoch nicht im Einzelnen dargestellt werden. Die Prognose der Materialien wurde zum Beispiel auf Betreiberebene in weitere Unterposten (Kraftsfahrzeugstoffe, Chemikalien, andere Verbrauchsgüter) aufgegliedert. In der Prognoserechnung wird jeweils für jeden Unterposten der Kostenanteil spezifiziert, der bezüglich der Abwassermenge variabel ist. Aus Gründen der Darstellbarkeit werden hier sämtliche Betriebskosten unter einer Kategorie zusammengefasst.

Die Kapitalkosten sind ebenfalls zusammengefasst und bestehen aus den kalkulatorische Zinsen und den kalkulatorischen Abschreibungen. Die Datengrundlage für die Prognose der beiden Kostenarten basiert auf den jährlich veranschlagten kalkulatorischen Zinsen und Abschreibungen sowie auf individuellen Annahmen bezüglich ihrer zukünftigen Entwicklung. Die Prognose der Kapitalkosten wird ebenfalls mithilfe der Betreiber vor Ort prognostiziert, somit können individuelle Investitionsstrategien und Erfahrungen implizit berücksichtigt werden. Sowohl die Betriebs- als auch die Kapitalkosten abzüglich nicht gebührenfähiger Posten werden daraufhin mithilfe der prognostizierten Abwassermenge sowie eines für jede Kostenart individuell festlegbaren jährlichen Preissteigerungsniveaus prognostiziert.

In der Gebührenprognose wird nach den Vorgaben des Kommunalabgabengesetzes (KAG) vorgegangen und die umlagefähigen Kosten direkt auf die Gebühren umgelegt. Von Änderungen des KAG oder sich ändernden Rahmenbedingungen wird abstrahiert. Einen Überblick über die Eingangsdaten und den Berechnungsablauf gibt **Bild 3**.

Im zweiten Schritt, der Nettoprognose, werden die einzelnen ursächlichen Effekte des in der Bruttoprognose nachgewiesenen Gebührenanstiegs isoliert voneinander betrachtet, um die zweite Forschungsfrage zu beantworten: Welchen Anteil haben der demografische Wandel bzw. andere Effekte an den Anstiegen der Gebührenbelastungen pro Haushalt? In der Nettoprognose wird zwischen den Auswirkungen der sinkenden Bevölkerungsanzahl (demografischer Effekt), des rückläufigen häuslichen Abwasseranfalls (Spareffekt), des rückläufigen industriellen Abwasseranfalls (Industrieeffekt), der Entwicklung der Betriebskosten (Betriebskosteneffekt) sowie der Kapitalkosten (Kapitalkosteneffekt) auf die Gebührenbelastung der Haushalte differenziert. Für die Nettoprognose werden cetris paribus jeweils nur die zu analysierenden Parameter berücksichtigt und zwar in Höhe der getroffenen Annahme der Betreiber. Beispielsweise hat zur Untersuchung des Demografieeffektes in Bautzen nur die Annahme zum Bevölkerungsrückgang in Bautzen von 3,2 % einen Einfluss auf das Endergebnis, alle anderen Parameter, wie die Entwicklung der Kapital- oder Betriebskosten oder die Veränderung der spezifischen Abwassermenge, werden auf dem Niveau von 2009 fortgeschrieben. Für die Untersuchung des Demografieeffektes im AZV Spreequellen und in Gladbeck wurden entsprechend die spezifischen Annahmen zur Bevölkerungsentwicklung aus Gladbeck (–7,3 %) und dem AZV Spreequellen (–7,6 %) verwendet. Da nur die bedeutendsten Effekte betrachtet wurden und sich die Effekte zum Teil gegenseitig beeinflussen, können die einzelnen Nettoeffekte nicht zu den Ergebnissen der Bruttoprognose aufsummiert werden. Zudem werden in der Bruttoprognose noch weitere Effekte berücksichtigt, wie zum Beispiel die Veränderung der Haushaltsgröße und der Anschlussgrad, die dämpfend auf die Gebührenbelastung der Haushalte wirken. Die Ergebnisse illustrieren jedoch die Richtung und Stärke der einzelnen Effekte sehr gut.

Für die Beantwortung der dritten Forschungsfrage wird eine Sensitivitätsanalyse durchgeführt. Im Rahmen dieser Analyse werden mögliche Änderungen in den Annahmen der Fallstudienpartner variiert, um dem hohen Grad an Unsicherheit solcher Prognosen gerecht zu werden und die Auswirkungen möglicher Variationen in den Annahmen sichtbar zu machen. Ebenso wie in der Nettoprognose, werden die übrigen Parameter auf dem Niveau von 2009 fortgeschrieben. Zum Beispiel geht der AZV Spreequellen von keiner weiteren Reduzierung des spezifischen Abwasseranfalls (Spareffekt) aus. In der Sensitivitätsanalyse wird untersucht, um wie viel Prozent sich die Gebührenbelastung der Haushalte ändert, wenn der spezifische Abwasseranfall sich um ± 1 % bis ± 20 % ändert. In der Sensitivitätsanalyse werden neben den Annahmen bzgl. des spezifischen Schmutzwasseranfalls *(Spareffekt)* weiterhin die Annahmen bzgl. des industriellen Schmutzwasseranfalls *(Industrieeffekt)* sowie des demografischen Wandels *(Demografieeffekt)*, der Kapitalkosten *(Kapitalkosteneffekt)* und der Betriebskosten *(Betriebskosteneffekt)*[4] variiert. Die Sensitivitätsanalyse ist somit der Nettoprognose ähnlich, allerdings arbeitet sie mit festen prozentualen Veränderungen.

Die Ergebnisse der Prognose werden sowohl in Gebühren pro Kubikmeter (siehe Formel 1) als auch in Form der durchschnittlichen Gebührenbelastung pro Haushalt (Formel 2) dargestellt. Häufig werden Gebührenvergleiche ausschließlich auf Basis der Kubikmeterpreise oder anhand eines bundesdeutschen Musterhaushaltes durchgeführt [25, 26]. Dabei werden jedoch die unterschiedlichen Gebührenerhebungsverfahren (Grund- und Regenwassergebühr) nicht berücksichtigt und unterschiedliche Pro-Kopf-Wasserverbräuche ignoriert.

$$\text{Abwassergebühr pro m}^3 = \frac{\text{(Schmutzwasserkosten-Grundgebühreneinnahmen)}}{\text{Schmutzwassermengen}} \quad (1)$$

[4] Im Gegensatz zur Nettoprognose wird in der Sensitivitätsanalyse aus technischen Gründen von einer für alle Kostenarten (Energie, Personal etc.) einheitlichen Veränderungsrate ausgegangen.

$$\text{Gebührenbelastung pro } HH = \text{(Abwassergebühr pro m}^3 \times \text{spez. Schmutzwassermenge} + \frac{\text{(Grundgebühreneinnahmen)}}{\text{Einwohneranzahl)}} \times \text{Haushaltsgröße} \quad (2)$$

3. Ergebnisse

3.1 Annahmen und Eingangsparameter für die Prognose

Grundvoraussetzung für die Auswahl der Fallstudien war die Betroffenheit vom demografischen Wandel. Alle drei Fallstudienpartner sind vom demografischen Wandel im Prognosezeitraum 2009–2020 betroffen[5]. Gladbeck muss sich auf einen Bevölkerungsrückgang von 7,3 % einstellen. Der AZV Spreequellen rechnet mit einem Rückgang von 7,6 %, Bautzen mit einem Rückgang von 3,2 %.[6] Leicht abgedämpft werden kann der Bevölkerungsrückgang durch eine Erhöhung des Anschlussgrades. Im AZV Spreequellen wird eine Erhöhung des Anschlussgrades von 93 % auf 94,5 % und in Bautzen von 98 % auf 99 % angestrebt, während in Gladbeck keine weitere Erhöhung des Anschlussgrades geplant ist (siehe auch **Tabelle 1**).

Die zuvor beschriebenen Ost-West-Unterschiede im Wasserverbrauch spiegeln sich auch in den drei Fallstudien wider. Während Bautzen und der AZV Spreequellen von etwa 24 bzw. 32 m³ pro Einwohner und Jahr an Schmutzwasseranfall ausgehen, fallen in Gladbeck 45 m³ pro Einwohner an. In Bautzen wird davon ausgegangen, dass der ohnehin niedrige Schmutzwasseranfall sich nur um weitere 1,3 % bis 2020 reduziert. Im AZV Spreequellen wird mit keinem weiteren Rückgang gerechnet. In Gladbeck hingegen stellt man sich auf einen Rückgang von 16,3 % ein. Bezüglich des industriellen Schmutzwasseranfalls wurde für den AZV Spreequellen die Annahme getroffen, dass dieser sich in Zukunft nicht verändern wird. In Bautzen wird mit einer leichten Abnahme des industriellen Schmutzwasseranfalls von 3,8 % im Prognosezeitraum 2009–2020 gerechnet. In Gladbeck wird aufgrund des Strukturwandels von einem Rückgang des industriellen Schmutzwasseranfalls von 9,8 % ausgegangen.

Der sich aus den getroffenen Annahmen zu den Betriebskosten ergebende Anteil der Fixkosten[7] beläuft sich auf 95 % in Gladbeck und im AZV Spreequellen und

[5] Damit sind die drei Fallstudien mäßig stark vom demografischen Wandel betroffen, wenn sie zum Beispiel mit Hoyerswerda verglichen werden, das sich laut Bertelsmann Stiftung auf einen Bevölkerungsrückgang von über 26 % im Zeitraum 2006–2020 einstellen muss.

[6] In Bautzen wurde auf Daten des Statistischen Landesamtes, in Gladbeck auf Daten des städtischen Statistikbeauftragten und beim AZV Spreequellen auf Daten des Statistischen Landesamtes sowie auf eigene Annahmen zurückgegriffen.

[7] Genauer genommen handelt es sich um Kosten, die nicht von der Abwassermenge abhängig sind.

Tabelle 1. Annahmen und Eingangsparameter für die Bruttoprognose.

Betreiber	Gladbeck			Bautzen			AZV Spreequellen		
Jahr	2009	2020	Änderung in %	2009	2020	Änderung in %	2009	2020	Änderung in %
Einwohner (E)	76 771	71 200	–7,3 %	41 172	39 847	–3,2 %	14 400	13 300	–7,6 %
Personen pro Haushalt	2,6	2,5	–3,8 %	1,88	1,84	–2,1 %	4,51	4,10	–9,1 %
Anschlussgrad	0,99	0,99	0,0 %	0,98	0,99	1,1 %	93,04 %	94,48 %	1,5 %
Spez. Abwasseranfall in m³/E/Jahr	45,83	41,36	–9,8 %	24,47	24,15	–1,3 %	32,00	32,00	0,0 %
in L/E/Tag	125,6	113,3	–9,8 %	67,0	66,2	–1,3 %	87,7	87,7	0,0 %
Industrieller Schmutzwasseranfall in m³	750 000	676 875	–9,8 %	767 353	738 235	–3,8 %	13 463	13 463	0,0 %
Häuslicher Schmutzwasseranfall in m³	3 482 925	2 915 239	–16,3 %	983 830	923 344	–6,1 %	428 736	402 112	–6,2 %
Investitionskosten in Euro	5 504 252	7 196 279	30,7 %	1 953 102	1 953 102	0,0 %	868 400	915 000	5,4 %
Betriebskosten in Euro	6 256 160	9 556 497	53 %	3 163 541	3 835 270	21 %	1 197 434	1 525 365	27%

auf 89 % in Bautzen. Die Kapitalkosten entwickeln sich in Abhängigkeit von der gewählten Investitionsstrategie. Die hier betrachteten Betreiber verfolgen unterschiedliche Investitionsstrategien. In Gladbeck steigen die Kapitalkosten im Prognosezeitraum um fast 40 %. In Bautzen wird von einem konstanten Verlauf der Kapitalkosten ausgegangen und im AZV Spreequellen von einem leichten Anstieg von etwas mehr als 5 % bis zum Jahr 2020.

Die Gebührenerhebungsverfahren der drei Fallstudienpartner weisen folgende Unterschiede auf: Bautzen erhebt ausschließlich eine verbrauchsabhängige Gebühr. Gladbeck stellt sowohl eine verbrauchsabhängige Gebühr als auch Regenwassergebühren in Rechnung. Der AZV Spreequellen wendet ebenfalls den Splittingmaßstab an und erhebt zusätzlich eine Grundgebühr in Abhängigkeit von der Anschlussgröße.[8]

3.2 Ergebnisse der Bruttoprognose

Basierend auf den betreiberspezifischen Annahmen wurde die Bruttoprognose durchgeführt, d.h. eine möglichst realistische Prognose unter Berücksichtigung sämtlicher Einflussfaktoren inkl. der Entwicklung der Betriebs- und Kapitalkosten, um eine Antwort auf die erste Forschungsfrage geben zu können: Um wie viel Prozent steigen die Abwassergebühren bis zum Jahr 2020? In **Bild 4** sind die Ergebnisse dieser Bruttoprognose dargestellt.[9]

Die Bruttoprognose zeigt, dass tatsächlich mit empfindlichen Gebührenanstiegen bei allen drei Betreibern zu rechnen ist. Die Gebührenbelastung der Haushalte steigt im Zeitraum 2009–2020 in Gladbeck um 50 %, in

[8] Im hier verwendeten Gebührenprognoseverfahren werden die Entwicklungen bei den Regenwasser- und Grundgebühren ebenfalls modelliert und fließen auch in die Prognose ein. Sie werden hier jedoch nicht weiter diskutiert.

[9] Auf die Darstellung der Kostendaten wird an dieser Stelle verzichtet. Die Prognose der Kostendaten ist jedoch in dem Gebührenprognoseverfahren integriert und fließt in die Ergebnisse mit ein.

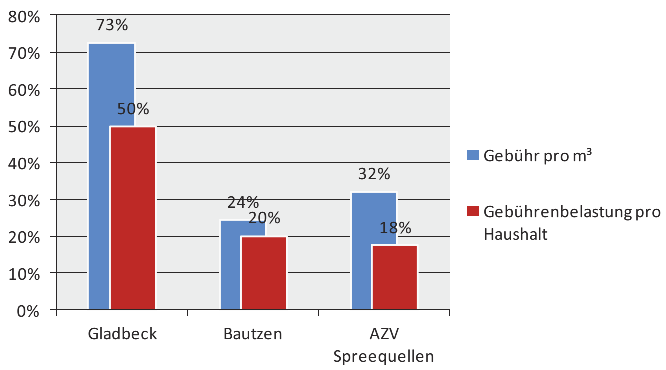

***Bild 4**. Prozentualer Anstieg der Gebührenbelastung pro Haushalt (2009–2020).*

Bautzen um 20 % und im AZV Spreequellen um 18 %. Die Gebühren pro Kubikmeter steigen in Gladbeck um 73 % und im AZV Spreequellen um 32 % und in Bautzen um 24 % an. Auffällig ist die hohe Differenz zwischen der Entwicklung der Haushaltsbelastung einerseits und den Gebühren pro Kubikmeter andererseits bei den beiden Betreibern in Gladbeck und im AZV Spreequellen. In Bautzen hingegen fällt im Vergleich zu den beiden anderen Betreibern die Differenz auffällig gering aus. Ursache hierfür sind die unterschiedlichen Gebührenerhebungsverfahren und unterschiedliche Haushaltsgrößen. In Bautzen wird ausschließlich eine mengenabhängige Abwassergebühr erhoben, das bedeutet, dass Änderungen 1 : 1 in die Abwassergebühr pro Kubikmeter einfließen, wohingegen in Gladbeck und im AZV Spreequellen noch zusätzliche, vom Wasserverbrauch unabhängige, Gebührenbestandteile hinzukommen. In Gladbeck werden neben den Kubikmetergebühren auch Gebühren für die versiegelten Flächen (gesplitteter Gebührenmaßstab) erhoben und in Zittau werden zusätzlich Grundgebühren erhoben. Fraglich ist nun, was die Ursachen für die empfindlichen Gebührenerhöhungen im Einzelnen sind. Dazu wird im nächsten Schritt die Nettoprognose durchgeführt.

3.3 Ergebnisse der Nettoprognose

Die Nettoprognose untersucht den Einfluss des demografischen Wandels bzw. anderer Effekte auf die steigende Gebührenbelastung der Haushalte. Als weitere Gebühren beeinflussende Effekte werden neben dem reinen Bevölkerungsrückgang (Demografieeffekt) und dem Rückgang des häuslichen Abwasseranfalls (Spareffekt) auch die Entwicklung der Betriebskosten (Betriebskosteneffekt) und die Entwicklung der Kapitalkosten (Kapitalkosteneffekt) betrachtet. Die Ergebnisse für alle Effekte im Überblick sind in **Bild 5** dargestellt. Im Folgenden werden die Ergebnisse der einzelnen Effekte kurz diskutiert.

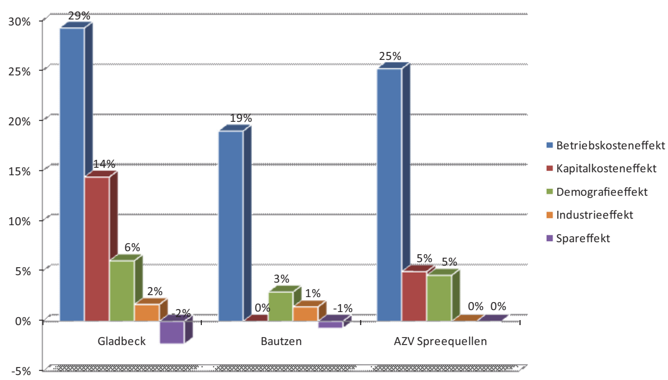

***Bild 5**. Veränderung der Gebührenbelastung pro Haushalt (2009–2020).*

3.3.1 Demografieeffekt

Die Auswirkungen des demografischen Wandels auf die Abwassergebühren führen in Form eines reinen Bevölkerungsrückganges bei einer Fortschreibung der übrigen Annahmen auf dem Niveau von 2009 zu einem leichten Anstieg der Abwassergebühren pro Kubikmeter. Durch die durch den Bevölkerungsrückgang verursachte Abnahme der Abwassermenge und durch den damit verbundenen Rückgang der variablen Kosten kommt es teilweise sogar zu minimalen Einsparungen (< 1 %) bei den Betriebskosten. Dieses Ergebnis beruht auf den Annahmen der Betreiber, dass mögliche technische Probleme aufgrund des demografischen Wandels wie eine Zunahme der Spülintervalle etc. im Rahmen der üblichen Wartungsarbeiten behoben werden können und damit keine steigenden Betriebskosten verursachen. Insgesamt führt die kleiner werdende Bevölkerungszahl (-7,3 %) in Gladbeck zu einem Anstieg der Gebührenbelastung der Haushalte um 6 %. In Bautzen rechnet man mit einem Rückgang der Bevölkerung um 3,2 %, der für einen Anstieg der Haushaltsbelastung um 3 % verantwortlich ist. Der Bevölkerungsrückgang im AZV Spreequellen um 7,6 % führt zu einer steigenden Belastung der Haushalte um 5 %. Der demografische Effekt schlägt nicht ganz 1 : 1 auf die Haushaltsbelastung durch, da die variablen Betriebskosten vom Demografieeffekt beeinflusst werden und leicht sinken.

3.3.2 Spareffekt

Der Spareffekt berücksichtigt ausschließlich die Annahmen der Betreiber zum spezifischen Abwasseranfall. Im AZV Spreequellen wurde die Annahme getroffen, dass es zu keinem weiteren Rückgang des spezifischen Abwasseranfalls kommt. Entsprechend hat der Spareffekt im AZV Spreequellen keine Auswirkungen. Der rückläufige spezifische Wasserverbrauch in Gladbeck (–9,8 %) und in Bautzen (-1,3 %) führt bei Konstanz aller übrigen Annahmen zwar zu steigenden Kubikmetergebühren von jeweils 8,3 % bzw. 0,7 %, die Gebührenbelastung pro Haushalt nimmt jedoch um 2 % in Gladbeck bzw. 1 % in Bautzen ab. Dieses Ergebnis differenziert bisherige Aussagen, z. B. von *Leist* [27, S. 174], dass Wassersparen auch zu höheren Haushaltsbelastungen führt. Ursächlich für die hier nachgewiesene sinkende Haushaltsbelastung ist, dass der Schmutzwasseranteil der Industrie laut Annahme konstant bleibt. Bei steigenden Kubikmetergebühren führt dies dazu, dass die Industrie einen entsprechend größeren Teil der Gebührenbelastung zu tragen hat, während die Haushalte durch eine Reduzierung der verbrauchten Menge ihre Gesamtbelastung reduzieren können. Nur wenn das industrielle Schmutzwasser in einem stärkeren Verhältnis als das häusliche Schmutzwasser abnimmt, kommt es auch zu steigenden Haushaltsbelastungen durch Wassersparen. In den bisherigen veröffentlichten Modellrechnungen (siehe Kapitel 1.2

Stand des Wissens) wurde der industrielle Schmutzwasseranteil nicht berücksichtigt.

3.3.3 Industrieeffekt

Im Gegensatz zum zuvor beschriebenen Spareffekt, in dem Veränderungen des häuslichen Abwasseranfalls untersucht werden, beschreibt der Industrieeffekt die Auswirkungen eines veränderten industriellen Abwasseranfalls. In Gladbeck reduziert sich der industrielle Abwasseranfall um 9,8 % und verursacht damit einen Anstieg der Gebührenbelastung der Haushalte im Jahr 2020 von 2 % im Vergleich zum Jahr 2009. In Bautzen wird mit einer Abnahme des industriellen Schmutzwasseranfalls von 767 000 m^3 auf 738 000 m^3 um 3,8 % gerechnet. Dies führt zu einem Anstieg der Haushaltsbelastung in Bautzen von etwa 1 %. Im AZV Spreequellen wird mit keiner Veränderung des industriellen Schmutzwasseranfalls gerechnet, entsprechend kommt es zu keinen Veränderungen der Haushaltsbelastungen.

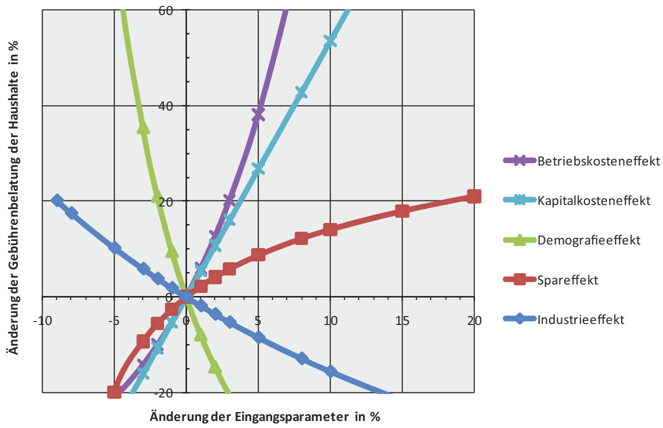

***Bild 6**. Veränderung der Gebührenbelastung der Haushalte (2009–2020).*

3.3.4 Betriebskosteneffekt

Bei Fortschreibung sämtlicher Annahmen, bis auf die Entwicklung der Betriebskosten, auf dem Niveau von 2009 zeigt sich, dass der Anstieg der Betriebskosten zu einem Anstieg der Gebührenbelastung der Haushalte um 29 % in Gladbeck, um 19 % in Bautzen und um 26 % beim AZV Spreequellen führt. Damit ist die Entwicklung der Betriebskosten der bedeutendste Gebührentreiber in allen drei Fallstudien. Im Vergleich zum Bevölkerungsrückgang fließt der Betriebskosteneffekt mit jährlich etwa 0,5 % – 3 % pro Jahr je nach Kostenart in die Gebührenberechnung ein, wohingegen der demografische Wandel mit -0,29 % bzw. -0,69 % pro Jahr ein vergleichsweise moderater Gebührentreiber ist. Insbesondere die Steigerung der Personalkosten trägt mit einem bedeutenden Anteil zum Anstieg der Betriebskosten bei. Die Energiekosten weisen ebenfalls eine deutliche Steigerung auf. Die Energiekostenanteile an den Gesamtkosten sind jedoch bei den drei Betreibern relativ gering.

3.3.5 Kapitalkosteneffekt

In der Nettoprognose werden die Auswirkungen der unterschiedlichen Investitionsstrategien bzw. Bewertungsverfahren der drei Betreiber deutlich. In Bautzen wird ein budgetärer Ansatz verfolgt und die Kapitalkosten in Zukunft auf konstantem Niveau gehalten. In Gladbeck wird mit einem jährlichen Anstieg der Kapitalkosten (kalk. Anschreibungen und Zinsen) von 2,5 % gerechnet.[10] Im AZV Spreequellen wird von einem Anstieg der Kapitalkosten von 0,49 % pro Jahr ausgegangen.[11] Da Kapitalkosten bei den drei Betreibern etwa 30 % – 40 % der gebührenfähigen Kosten ausmachen, hat deren Entwicklung einen entsprechend großen Einfluss auf die Entwicklung der Gebühren. Dementsprechend kommt es bei der Nettoprognose des Kapitalkosteneffektes zu einem leichten Anstieg der Gebührenbelastung der Haushalte von 5 % im AZV Spreequellen und zu einem Anstieg von 18 % in Gladbeck. In Gladbeck steigt damit der Anteil der Kapitalkosten an den Gesamtkosten von 42 % auf 48 % bis zum Jahr 2020. In Bautzen und im AZV Spreequellen bleibt der Anteil an den Gesamtkosten nahezu konstant.

3.4 Ergebnisse der Sensitivitätsanalyse

Um zu untersuchen, welche Annahmen bei möglichen Fehleinschätzungen zu den größten Abweichungen führen würden, wurden für die drei Betreiber Sensitivitätsanalysen durchgeführt. Die Ergebnisse werden exemplarisch am Fallbeispiel Gladbeck illustriert, da sich bei allen drei Fallstudien gleiche Verläufe ergaben.

Die Steigung der Kurvenverläufe gibt Aufschluss über den Grad der Sensitivität. Je sensibler die Gebührenbelastungen der Haushalte auf Veränderungen der Annahmen reagieren, desto steiler verläuft die Kurve. Eine nahezu waagerecht verlaufende Kurve würde auf den sehr geringen Einfluss des Effektes auf das Endergebnis hinweisen. Wie in **Bild 6** dargestellt, ergibt die Variation der Annahmen des Demografieeffektes die steilste Kurve. Eine Variation der Annahmen des Betriebskosteneffektes und des Kapitalkosteneeffektes führt

Erratum: Die beiden letzten Sätze auf dieser Seite wurde im Vergleich zur GWF-Orginalausgabe angeändert

[10] In Gladbeck werden die Abschreibungen (3,5 % jährlicher Anstieg) auf Basis von Wiederbeschaffungszeitwerten kalkuliert. Damit werden implizit erwartete Preissteigerungen z. B. bei Sanierungsarbeiten berücksichtigt, um in Zukunft real genügend Finanzmittel zur Instandhaltung der Infrastruktur zur Verfügung zu haben. Vor dem Hintergrund eines nicht ausgeglichenen Haushaltes ist Gladbeck verpflichtet, seine Beiträge und Gebühren nach den höchstmöglichen zulässigen Ansätzen des KAG NRW zu erheben.

[11] Je nach Höhe der Inflation stehen in Bautzen und im AZV-Spreequellen in Zukunft real sinkende Mittel zur Instandhaltung zur Verfügung.

auch zu sehr starken Änderungen der Gebührenbelastung der Haushalte bis zum Jahr 2020. Die Annahmen bzgl. des Spareffektes und des Industrieeffektes weisen einen etwas flacheren Verlauf auf. Alle fünf untersuchten Effekte reagieren damit sehr sensibel auf mögliche Variationen der Annahmen.

4. Zusammenfassung und Diskussion

Wie sich in den hier vorgestellten Fallstudien gezeigt hat, droht es in Zukunft bei allen drei Betreibern zu einem empfindlichen Anstieg der Gebührenbelastungen der Haushalte zu kommen. Die durchschnittlichen jährlichen Anstiege der Gebührenbelastungen der Haushalte im AZV Spreequellen und Bautzen bleiben jedoch noch unterhalb von 1,9 % und in Gladbeck unter 4,2 %. Im Vergleich zu anderen Infrastrukturdienstleistungen, wie z. B. der Energieversorgung, können die Anstiege im AZV Spreequellen und Bautzen als moderat bezeichnet werden. Wie in der Nettoprognose gezeigt wurde, ist die in Gladbeck in Zukunft vergleichsweise hohe Gebührenbelastung vor allem auf die geplante Investitionstätigkeit und die Bewertung nach Wiederbeschaffungszeitwerten zurückzuführen. Gladbeck berücksichtigt damit zu erwartende Preissteigerungen, die auch die zukünftige Investitionstätigkeit betreffen wird. Die Entscheidung, ob nach Wiederbeschaffungszeitwert oder Anschaffungswert bewertet wird, ist somit eine strategisch-politische Entscheidung, ob die Gebührenstabilität oder die technische Instandhaltung im Vordergrund stehen soll.

In der Nettoprognose wurden die Auswirkungen des demografischen Wandels auf die Abwassergebühren, isoliert von anderen Einflussgrößen, analysiert und mit diesen verglichen. Wie sich gezeigt hat, führt der Rückgang der Bevölkerung zu einem Anstieg der Gebühren fast im Verhältnis 1 : 1. Als der wesentliche Treiber der Gebührenbelastung der Haushalte hat sich die Entwicklung der Betriebskosten (insbesondere bei Personal und Energie) herausgestellt. In diesem Zusammenhang ist der Begriff der Fixkostenproblematik zu hinterfragen. Vielmehr müsste von einem Fixkostenvorteil gesprochen werden, da der hohe Fixkostenanteil dämpfend auf die stark Gebühren treibenden Betriebskosten wirkt. Wie sich in den drei Fallstudien gezeigt hat, ist jedoch der Demografieeffekt, in dessen Zusammenhang der Begriff hauptsächlich genutzt wird, beinahe zu vernachlässigen. Die Entwicklung der Betriebskosten und die Investitionsstrategie haben einen signifikant stärkeren Einfluss auf die Haushaltsbelastungen als der Demografieeffekt.

Positiv auf die Gebührenbelastung der Haushalte wirkt sich unter den getroffenen Annahmen das Wassersparen der Haushalte aus. Eine Reduzierung des spezifischen Abwasseranfalls erhöht zwar die Kubikmeterpreise, die Gebührenbelastung der Haushalte kann jedoch zulasten der Industrie gesenkt werden.

Die Gefahr von möglichen Teufelskreisen, die primär durch den demografischen Wandel verursacht werden, und zu einer nicht mehr steuerbaren Kostenspirale führen, konnte in den drei Fallstudien nicht festgestellt werden. Dies liegt zum einen an dem sich hier positiv auswirkenden Spareffekt und zum anderen an der Tatsache, dass alle drei Betreiber mögliche technische Beeinträchtigungen, die durch den demografischen Wandel verursacht wurden, im Rahmen der üblichen Instandhaltungsarbeiten bewältigen konnten. Angesichts der hohen Relevanz der Kapitalkosten bzw. der zukünftigen Investitionsstrategie ist es ratsam, die vorhandenen Anlagegüter und deren zukünftige Instandhaltung und den Ausbau entsprechend zu steuern, z. B. in Form einer entsprechenden Sanierungsstrategie.

Die mit den getroffenen Annahmen verbundene Unsicherheit wurde mithilfe der Sensitivitätsanalyse herausgearbeitet. Diese hat gezeigt, dass insbesondere Änderungen in den Annahmen bezüglich der Betriebs- und Kapitalkosten sowie zur Entwicklung der Einwohneranzahl (Demografieeffekt) zu sehr starken Änderungen des Endergebnisses führen würden. Daher ist es ratsam, die in der Prognose getroffenen Annahmen regelmäßig zu hinterfragen und zu aktualisieren. Insbesondere vor dem Hintergrund, dass sich in den kommenden Dekaden der demografische Wandel weiter verstärken wird, ist ein ständiges Controlling der entsprechenden Größen, z. B. auf Basis des Gebührenprognoseverfahrens, zu empfehlen.

Ergänzende Angaben

Das dem Artikel zugrunde liegende Gebührenprognoseverfahren wurde am Lehrstuhl für Betriebswirtschaftslehre, insbesondere Betriebliche Umweltökonomie, an der Technischen Universität Dresden in Zusammenarbeit mit dem Institut für Siedlungs- und Industriewasserwirtschaft (ebenfalls TU Dresden) im Rahmen des Projektes „Auswirkungen des demografischen Wandels auf die Siedlungsentwässerung" entwickelt. Finanziert wurde das Projekt vom Bundesministerium für Bildung und Forschung (FKZ: 02WA0918), vom Sächsischen Ministerium für Umwelt und Landwirtschaft, vom Sächsischen Landesamt für Umwelt und Geologie und von der Emschergenossenschaft. Für die finanzielle Unterstützung möchten wir uns an dieser Stelle recht herzlich bedanken. Ganz besonders bedanken möchten wir uns für die gute Zusammenarbeit mit den drei Praxispartnern: dem Abwasserbetrieb Bautzen, der Süd-Oberlausitzer Wasserversorgungs- und Abwasserentsorgungsgesellschaft mbH (SOWAG) und der Stadt Gladbeck.

Literatur

[1] Statistisches Bundesamt, Fachserie 19 / Reihe 2.1 - Umwelt - Öffentliche Wasserversorgung und Abwasserbeseitigung. Wiesbaden, 2009.

[2] Bundesamt für Bauwesen und Raumordnung: Raumordnungsprognose 2020/2050. Band 23, Selbstverlag des Bundesamtes für Bauwesen und Raumordnung, Bonn 2006.

[3] *Berger, C., Lohaus, J.,* Wittner, A. und *Schäfer, R.:* Zustand der Kanalisation in Deutschland. Ergebnisse der ATV-DVWK-Umfrage 2001. Korrespondenz Abwasser 49 (2002) Nr. 3, S. 302–311.

[4] Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall (DWA): Wirtschaftsdaten der Abwasserbeseitigung – Ergebnisse einer gemeinsamen Umfrage der Deutschen Vereinigung für Wasserwirtschaft, Abwasser und Abfall und des deutschen Städtetages sowie des deutschen Städte- und Gemeindebundes. Online verfügbar unter: www.dwa.de

[5] *Wolf, M.* und *Milojević, N.:* Entwicklung von nachhaltigen Kanalsanierungsstrategien. bbr – Fachmagazin für Brunnen- und Leitungsbau (2006) Nr. 6, S. 22–33.

[6] *Geiler, N.:* Wassersparen und virtuelles Wasser – unser „verborgener" Wasserkonsum. Referat anlässlich einer Tagung der Ev. Akad. Tutzing. Skript online unter: www.umweltbildung-bayern.de/...Wassertagung/Virtuelles_Wasser_Nikolas_Geiler.pdf

[7] *Schleich, J.* and *Hillenbrand, T.:* Determinants of Residential Water Demand in Germany. Ecological Economics 68 (2009) No. 6, p. 1756–69.

[8] *Bellefontaine, K.:* Auswirkungen der demografischen Entwicklung auf die Gebührenkalkulation und die Gebührenentwicklung. In: Demografischer Wandel. Herausforderungen und Chancen für die Deutsche Wasserwirtschaft. Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V. (DWA). Hennef, 2008, S. 121–134.

[9] KfW Bankengruppe: Auswirkungen des demographischen Wandels auf die Ver- und Entsorgungsnetze für Trinkwasser und Abwasser in den Kommunen. In: Der Wirtschaftsobserver Band 3/2006. Frankfurt am Main: KfW Research, 2006.

[10] *Just, T.:* Demografische Entwicklung verschont öffentliche Infrastruktur nicht. Deutsche Bank Research. Frankfurt am Main, 2004.

[11] *Lux, A.:* Wasserversorgung im Umbruch: Der Bevölkerungsrückgang und seine Folgen für die öffentliche Wasserwirtschaft. Frankfurt [u. a.]: Campus-Verl., 2009.

[12] *Schlör, H., Hake, J.-F.* and *Kuckshinrichs, W.:* Demographics as a new challenge for sustainable development in the German wastewater sector. International Journal of Environmental Technology and Management 10 (2009) No. 3/4, p. 327–352.

[13] *Birkholz, T.* und *Pfeiffer, W.:* Auswirkungen der demographischen Veränderungen auf die Ver- und Entsorgungsunternehmen in Mecklenburg-Vorpommern. gwf-Wasser|Abwasser 147 (2006) Nr. 9, S. 576–84.

[14] *Herz, R.* u. a.: Erfordernisse und Finanzierung der Anpassung der stadttechnischen Infrastruktur im Zuge des Stadtumbaus. Fakultät Bauingenieurwesen, Lehrstuhl für Stadtbauwesen, Institut für Stadtbauwesen und Straßenbau, Technische Universität Dresden. Dresden, 2002.

[15] *Mohajeri, S.:* Von der kommunalen zur regionalen Perspektive: Lösungsstrategie für eine zukunftsfähige Ver- und Entsorgung in schrumpfenden Regionen. In: Demografischer Wandel Herausforderungen und Chancen für die Deutsche Wasserwirtschaft. Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V. (DWA). Hennef, 2008, S. 212–226.

[16] *Seitz, H.:* Kommunalfinanzen bei schnell schrumpfender Bevölkerung in Ostdeutschland: Eine politikorientierte deskriptive Analyse. (2002).

[17] *Herber, W.* u.a.: Die demografische Entwicklung als Grundlage für den regionalen Wasserbedarfsnachweis der Hessenwasser GmbH & Co. KG. gwf-Wasser|Abwasser 148 (2007) Nr. 10, S. 684–90.

[18] *Herber, W.* u.a.: Die Wasserbedarfsprognose als Grundlage für den regionalen Wasserbedarfsnachweis der Hessenwasser GmbH & Co. KG. gwf-Wasser|Abwasser 149 (2008) Nr. 5, S. 426–434.

[19] *Roth, U.:* Bestimmungsfaktoren für Wasserbedarfsprognosen. gwf-Wasser|Abwasser 139 (1998) Nr. 2, S. S. 63–69.

[20] *Grossmann, J.* und *Hofmann, H.:* Integrierte Wasserbedarfsprognose, Teil 1: Erstellung eines innovativen Prognosemodells Für Hamburg Wasser. gwf-Wasser|Abwasser 149 (2008) Nr. 10, S. 758–63.

[21] *Kluge, T.* u.a.: Integrierte Wasserbedarfsprognose, Teil 2: Grundlagen und Methodik. gwf-Wasser|Abwasser 149 (2008) Nr. 10, S. 764–72.

[22] *Bächle, A.* u.a.: Prognose zur Trinkwasserbedarfsermittlung im Versorgungsgebiet der MVV Mannheim. gwf-Wasser|Abwasser 139 (1998) Nr. 2, S. 70–78.

[23] *Berger, H.* u.a.: Struktur und Entwicklung des Wasserverbrauchs in Wiesbaden. gwf-Wasser|Abwasser 139 (1998) Nr. 9, S. 566–74.

[24] *von Wangenheim, U.* und *Kern, J.:* Anwendung dynamischer Kalkulationsmethoden zur Ermittlung und Prognose kostendeckender Abwasserentgelte. Korrespondenz Abwasser 44 (1997) Nr. 2, S. 266–77.

[25] *Lichblau, K.:* INSM Abwassermonitor 2008 - Abwassergebühren im Vergleich – Die 100 größten deutschen Städte –. Bericht der IW Consult GmbH Köln, Institut der deutschen Wirtschaft Köln Consult GmbH, Köln, 2008.

[26] BdSt NRW (Bund der Steuerzahler Nordrhein-Westfalen) 2009: Die Abwassergebühren 2009. http://www.steuerzahler-nrw.de/Die-Abwassergebuehren-2009/1461c2271i1p350/index.html Stand: 01.03.2010

[27] *Leist, H.J.:* Wasserversorgung in Deutschland: Kritik und Lösungsansätze. München: oekom-Verlag, 2007.

[28] Bundesamt für Bauwesen und Raumordnung: Raumordnungsbericht 2009. Band 21, Selbstverlag des Bundesamtes für Bauwesen und Raumordnung, Bonn, 2005.

[29] *Berger, C.* und *Lohaus, J.:* Zustand der Kanalisation in Deutschland. Ergebnisse der DWA-Umfrage 2004. Korrespondenz Abwasser 52 (2004) Nr. 5, S. 528–539.

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5 Journal Article E1:

Nachhaltige Unternehmensführung mit der Delphi-Methode

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WISU-KOMPAKT

ÖKOLOGIE UND WIRTSCHAFT

Die Umweltgefährdung verlangt schnelle und nachhaltige Maßnahmen. Hier werden Instrumente vorgestellt, die zur Erhaltung der natürlichen Umwelt beitragen.

Nachhaltige Unternehmensführung mit der Delphi-Methode

*Wie sich die Delphi-Methode bei der nachhaltigen Unternehmensführung einsetzen lässt, wird am **Beispiel der Abwasserwirtschaft** verdeutlicht. Die Abwasserwirtschaft sammelt, transportiert und behandelt Abwasser und entsorgt die Reststoffe umweltgerecht. Das Abwasser kann aus dem häuslichen und industriellen Sanitärbereich sowie aus der Grundstücksentwässerung stammen. Für diese Aufgaben unterhält die Abwasserwirtschaft ein komplexes **Infrastruktursystem**. Neben Kanälen, Pumpenwerken und Kläranlagen werden auch Regenentlastungsbauwerke benötigt.*

Planungshorizonte, Fixkosten und demografische Entwicklung

Ein Großteil dieser Infrastruktur, allen voran die Kanäle, haben eine sehr lange Nutzungsdauer von teilweise über 100 Jahren (Abb. 1). Annahmen zu ihrer Größe und den Abwassermengen müssen also über mehrere Jahrzehnte im voraus getroffen werden. Dies macht es den Entscheidungsträgern schwer, auf sich verändernde Rahmenbedingungen wie den Klimawandel, den demografischen Wandel oder neue Schadstoffe, etwa Medikamentenrückstände, zu reagieren. Dies wird auch an der aktuellen Diskussion über die Folgen des demografischen Wandels bei den Abwassergebühren deutlich (vgl. Nowack et al.).

Abb. 1: Zeithorizonte der Planung

Wegen des hohen Anteils an Fixkosten (Abb. 2) könnten sich bei sinkender Bevölkerung die Abwassergebühren erhöhen. Fixkosten werden als die Kosten definiert, die bei geringerer Produktionsmenge bzw. Bevölkerungszahl nicht zurückgehen. In der Abwasserwirtschaft sind dies vor allem die Abschreibungen, die Zinsen und bis zu einem gewissen Grad (je nach Kündbarkeit und Personalpolitik) auch die Personalkosten. In Ostdeutschland wurden nach der Wende viele Abwasseranlagen für größere und zum Teil auch steigende Bevölkerungszahlen geplant. Die Betreiber sehen sich jedoch einer sinkenden Bevölkerung gegenüber. Ein Rückbau oder eine Verkleinerung der Kanäle ist nicht ohne weiteres möglich.

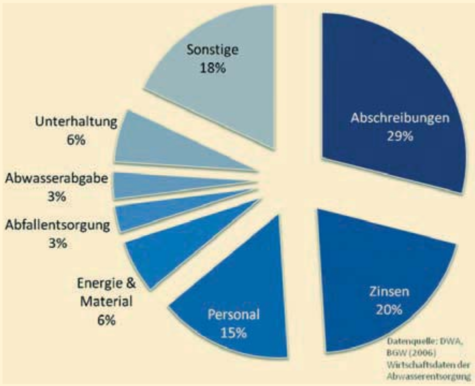

Abb. 2: Kostenstrukturen in der Abwasserwirtschaft

Das Beispiel macht deutlich, dass sich die Abwasserwirtschaft frühzeitig auf veränderte Rahmenbedingungen einstellen muss. Die zentralen Kernindikatoren wie die Einwohnerzahl und der Abwasserverbrauch stehen bereits unter Beobachtung. Wie können jedoch alle denkbaren Veränderungen, von neuen gesetzlichen Rahmenbedingungen bis zu bislang gäzlich unbekannten Schadstoffen, ermittelt und bewertet werden?

Delphi-Methode

Eine Lösung verspricht die Delphi-Methode (vgl. Günther/Endrikat, S. 202), die 1963 im Auftrag der US-Airforce von der RAND-Corporation entwickelt wurde. Dabei werden Experten mehrfach anonym befragt, wodurch die negativen Seiten von Gruppendiskussionen vermieden werden sollen. Die Experten können die anonymisierten Antworten der anderen Befragten einsehen und ihre eigene Meinung erläutern oder ggf. revidieren. Das Feedback erfolgt häufig in Form von statistischen Auswertungen (Mittelwerte, Quartilsverteilungen).

Beim Forschungsprojekt „Auswirkungen des demografischen Wandels auf die Siedlungsentwässerung" (www.demowas.de) wurde die Delphi-Methode mit dem Ziel eingesetzt, die wesentlichen Herausforderungen bei der Siedlungsentwässerung bis zum Jahr 2050 zu ermitteln. Bei der DEMOWAS-Delphi-Methode gab es zunächst zwei Runden:

- ***1. Delphi-Runde:** Hier wurden ca. 20 teilstrukturierte Interviews mit ausgewählten Experten aus Wissenschaft, Forschung und Praxis durchgeführt. Die Interviews wurden schriftlich festgehalten, anschließend ausgewertet und zusammengefasst. Bei den **ökologischen Herausforderungen** wurden z.B. diese Themen einbezogen:*
  - ***Klimawandel:** Er führt zu häufiger auftretendem Starkregen und Trockenperioden.*
  - ***Neue Schadstoffe:** Nanopartikel, Bakterien und Viren, Medikamentenrückstände und Hormone, Schwermetalle.*

  Mit den Ergebnissen der 1. Delphi-Runde liegen den Teilnehmern der 2. Delphi-Runde nicht nur bisherige Beiträge, sondern bereits eine mögliche Struktur der Inhalte vor.
- ***2. Delphi-Runde:** Die Ergebnisse der Synthese der ersten Runde wurden den Experten in der zweiten Delphi-Runde zur Kommentierung und Ergänzung vorgelegt. Dies beruhte auf dem Online-Diskussionsforum. Die Experten erhielten darüber hinaus die Möglichkeit, weitere Experten zu be-*

nennen, die ebenfalls an der Delphi-Umfrage teilnehmen sollten.

- ***3. Delphi-Runde (Variante):*** *Üblicherweise werden die Experten in einer anschließenden Runde gebeten, die Herausforderungen, etwa im Hinblick auf ihre Bedeutung für die Abwasserwirtschaft, ihren Eintrittszeitpunkt und auf mögliche Konsequenzen hin, zu bewerten. Die Ergebnisse lassen sich mithilfe von Roadmaps (Abb. 3) anschaulich darstellen.*

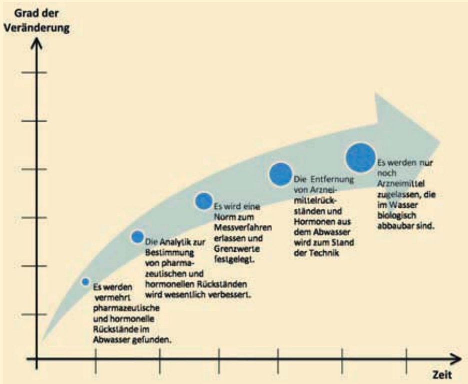

Abb. 3: Technologie-Roadmap am Beispiel von Arzneimittelrückständen

Szenarioentwicklung

Um dem bei Zukunftsstudien hohen Grad an Unsicherheit und den vielen von den Experten genannten Herausforderungen gerecht zu werden, wurden die wichtigsten Entwicklungen beim DEMOWAS-Projekt in Szenarien zusammengefasst (vgl. Günther/Nowack). Anhand dieser Szenarien konnten die Entscheidungsträger der Abwasserwirtschaft verschiedene Strategien entwickeln, wie sie die Herausforderungen meistern wollen.

Die Erfahrungen mit der Delphi-Methode beim DEMOWAS-Projekt haben gezeigt, dass sie nur gezielt eingesetzt werden sollte. Besonders geeignet erscheint sie, wenn mögliche zukünftige Störereignisse bzw. Herausforderungen identifiziert werden sollen, die bislang nur am Rande bzw. noch gar nicht in wissenschaftlichen Zeitschriften, Konferenzen oder Foren diskutiert wurden. Die Anonymität der Delphi-Methode spielt bei der Ermittlung sog. schwacher Signale eine besondere Rolle. Der Experte muss keine Kritik seitens anderer Experten befürchten, wenn er unkonventionelle Ideen äußert.

Der Aufwand, der mit einer Delphi-Studie verbunden ist, sollte jedoch nicht unterschätzt werden. Sie eignet sich deshalb weniger für kleine und mittlere Unternehmen, ist jedoch Verbänden, Ministerien und Forschungseinrichtungen bei Technologieprognosen zu empfehlen (vgl. Sartorius/Klobasa; BMBF). Letztlich können nur dann nachhaltige Entscheidungen getroffen werden, wenn sich die Verantwortlichen aller Optionen bewusst sind. Die Delphi-Methode ermöglicht es, diese Optionen zu ermitteln.

Prof. Dr. Edeltraud Günther/
Dipl.-Volksw. Martin Nowack, Dresden

Literatur:

Bundesministerium für Bildung und Forschung (BMBF): Technologievorausschau und Technologiebeobachtung. http://www.bmbf.de/de/6502.php. abgerufen am 21.3.2011.

Günther, E./Endrikat, J.: Die Delphi-Methode. In: WISU, 40. Jg. (2011), S. 202 f.

Günther, E./Nowack, M.: Szenarioplanung. In: WISU, 38. Jg. (2009), S. 340 f.

Just, T.: Demografische Entwicklung verschont öffentliche Infrastruktur nicht. In: Deutsche Bank Research, Aktuelle Themen: Demografie Spezial, 28.4.2004, Nr. 294. www.dbresearch.de. Abgerufen am 21.3. 2011.

Nowack, M./John, S./Tränckner, J./Günther, E.: Der demografische Wandel als Gebührentreiber in der Siedlungsentwässerung — Ein Vergleich des Demografieeffektes mit Spar-, Betriebskosten-, Kapitalkosten- und Industrieeffekten. In: gwf Wasser/Abwasser, Heft 11/2010, S. 1076 ff.

Sartorius, C./Klobasa, C.: Delphi-Befragung zu nachhaltigen wasserwirtschaftlichen Innovationen im Rahmen des Projektes Wasser 2050. Fraunhofer Institut für System- und Innovationsforschung. www.wasser 2050.de/ftp/delphi.pdf. Abgerufen am 21.3.2011.

ten. **Frontends** helfen, die Informationen eingängig darzustellen und ermöglichen eine einfache Navigation bei weiterführenden Analysen.

Perspektiven

Aus Akzeptanzgründen und um sie sichtbar zu machen, sollten die Ergebnisse der IS-gestützten Früherkennung in ein umfassendes Unternehmenssteuerungssystem integriert werden — eine wichtige Aufgabe für die Wirtschaftsinformatik und das Controlling in den nächsten Jahren. Die jüngste Wirtschaftskrise machte deutlich, dass eine Früherkennung von Risiken nicht nur ein Thema für Banken und Versicherungen, sondern für alle Wirtschaftssektoren ist.

IS-gestützte Früherkennungssysteme sind in erster Linie darauf ausgerichtet, potenzielle Risiken aufzuspüren. Durch strengere Regulierungen wird dies in Zukunft noch verstärkt. Allerdings darf die Suche nach **Chancen** (Ertragspotenzialen) dabei nicht aus dem Auge verloren werden. Die IS-Unterstützung bei der Früherkennung kann aber weder die **Erfahrungen von Führungskräften** noch die **menschliche Intuition** ersetzen, sondern sie — insbesondere bei Routinetätigkeiten — nur unterstützen.

Dr. Jörg H. Mayer, St. Gallen/
Neon Steinecke, BSc, Darmstadt

Literatur:

Aguilar, F.J.: Scanning the Business Environment. New York 1967.

Ansoff, H.I.: Managing Strategic Surprise by Response to Weak Signals. In: California Management Review, 18. Jg. (1975), H. 2, S. 21 ff.

Baum, H.-G./Coenenberg, A.G./Günther, T.: Strategisches Controlling. 4. Aufl., Stuttgart 2007.

Elofson, G.S./Konsynski, B.R.: Performing Organizational Learning with Machine Apprentices. In: Decision Support Systems, 10. Jg. (1993), S. 109 ff.

Hahn, D./Krystek, U.: Betriebliche und überbetriebliche Frühwarnsysteme für die Industrie. In: Zeitschrift für betriebswirtschaftliche Forschung, 31. Jg. (1979), S. 76 ff.

Horváth, P.: Controlling. 11. Aufl., München 2009.

Krystek, U./Herzhoff, M.: Szenario-Technik und Frühaufklärung: Anwendungsstand und Integrationspotential. In: Zeitschrift für Controlling und Management, 50. Jg. (2006), S. 305 ff.

Mayer, J.H.: IS-Architektur zur Unterstützung von Führungskräften. In: WISU, 40. Jg. (2011), S. 60 ff.

Mayer, J.H./Wurl, H.-J.: Strategische Früherkennung in industriellen Konzernen — ein pragmatischer Gestaltungsansatz. Forschungsbericht Universität St. Gallen, St. Gallen 2011.

Watson, H.J.: Tutorial: Business Intelligence — Past, Present, and Future. In: Communications of the Association for Information Systems, 25. Jg. (2009), H. 39, S. 487 ff.

6 Journal Article E2: Review of Delphi-based scenario studies

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Annex:

the coding scheme is available here:
http://tu-dresden.de/die_tu_dresden/fakultaeten/fakultaet_wirtschaftswissenschaften/bwl/bu/forschung/projekte/demografischer_wandel

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Review of Delphi-based scenario studies: Quality and design considerations

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ABSTRACT

For meaningful scenarios, creative input concerning possible future trends is crucial. Herman Kahn, the father of modern scenario planning, underlined the importance of "*thinking the unthinkable*" in a significant scenario study. "*Blessed with high intelligence, an assertive personality and the research capabilities of the RAND Corporation*," he could rely on genius forecasting. But how can this foresight be creative as well as simultaneously credible and objective if one does not possess Kahn's genius? In this article, we assess the incorporation of expert knowledge via the Delphi technique into scenario planning as a promising option. We discuss possible combinations and identify the span of design alternatives in the existing body of Delphi-based scenario studies through a systematic research review and provide recommendations on how a Delphi-based scenario study should be designed to ensure quality. We recommend focusing on the integration of the Delphi technique only in one phase of the scenario approach. In this way, the design options can be intentionally adjusted to the particular function. We further offer recommendations on how to accomplish this.

1. Introduction

In order to develop meaningful scenarios, creative input concerning possible future trends and developments is crucial. Herman Kahn, the father of modern scenario planning, underlined the importance of "*thinking the unthinkable*" in a significant scenario study. "*Blessed with high intelligence, an assertive personality and the research capabilities of the RAND Corporation*," he could rely on genius forecasting [1]. But how can this foresight process be creative, credible and objective if one does not possess Kahn's genius and resources? As MacKay and McKiernan [2] confirm, "*For most participants, these activities demand that they activate and utilize those artistic parts of the brain that normally lie dormant for long periods while they carry their daily routines…*" The Delphi technique itself is supposed to enhance creative thinking. According to Gupta and Clarke [3], it is "*one of the best known methods for dealing with open-ended and creative aspects of a problem because it motivates independent thought and gradual formation of group solutions.*" In this article, we assess the incorporation of expert knowledge via the Delphi technique into scenario planning as a promising option. We do this to give recommendations on how a Delphi-based scenario study should be designed to ensure the highest possible degree of quality. Therefore we address two research questions:

1. How can the Delphi technique enhance the quality of a scenario study?

The purpose here is to evaluate if a combination of the two methods is reasonable and contributes to a more effective scenario study.

2. What is the span of possible design options in the existing body of Delphi-based scenario studies?

Developed for military purposes by the RAND Corporation in the U.S. during the Cold War, both methods date back more than 50 years. Since then, several researchers have combined the two methods in very different ways. Therefore, a systematic research review that

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reflects the span of possible design options is needed. While the Delphi technique, in general, has been subject to several prior reviews [3–7] as well as scenario planning [8–13], no review on the combination of the two methods has been conducted.

2. Materials and methods

We develop the answer of the first research question by giving a short overview on the main design elements of scenario planning and the Delphi technique. Derived from the methodological literature, we present a generic scenario planning approach as well as the main functions of the Delphi technique and show in which steps of the scenario planning approach each Delphi function can be integrated. The impacts on the overall quality of scenarios will be discussed for each combination possibility. We do this based on quality criteria derived from general scientific quality criteria. The design options (design elements and functions) are taken in the next step, the systematic research review, as a basis.

To answer the second research question, we conduct a systematic research review and analyze the applied design options in the identified Delphi-based scenario studies. The review is conducted according to Cooper [14] and Fink [15] in combination with a content analysis approach [16].

We identified the relevant studies for the review by searching via the EBSCOhost interface the 12 databases of Academic Search Complete, Business Source Complete, EconLit with Full Text, E-Journals, Historical Abstracts, International Political Science Abstracts, Library, Information Science & Technology Abstracts, Literary Reference Center, MLA Directory of Periodicals, Risk Management Reference Center and TOC Premier. We used all databases accessible to us and excluded those that were out of focus such as the American Antiquarian Society (AAS) Historical Periodicals Collection Series 1 and 2, the ATLA Religion Database and the International Bibliography of

Table 1
Coding scheme.

Category	Subcategory	Question to answer	Example
Study	Author	Who is the author of the study?	Shiftan et al.
	Year	In which year was the study published?	2003
Focus of the study	Time	What is the time frame of the study?	30 years
	Geographic	What is the geographic focus of the study?	Tel Aviv Metropolitan Area
	Thematic	What is the thematic focus of the study?	Transport
Scenario planning	Scenario goal	What is the main goal of the scenario study?	Predictive + norm. (sustainability)
	Range of future states	How many scenarios are developed?	2
	Presentation of scenarios	How are the scenarios presented?	Scenario sketch
	Discontinuity	Does discontinuity (wildcards, etc.) play a role?	No
	Scenario logic	What are the determining factors of the scenarios?	Degree of probability & desirability
Delphi-Function	Function of the Delphi technique	Which Delphi functions are used?	Idea generation; judgment; consolidation
Delphi-Iteration	Number of rounds	How many rounds are conducted?	2
Delphi-Experts	Number of invited experts	How many experts are invited?	63
	Number of responding experts	How many experts joined the Delphi rounds?	1st: 28; 2nd: 18
	Selection of experts	Is explicit criteria for the selection of experts mentioned? If yes, which?	No
	Composition of the Delphi panel	What is the actual composition of the Delphi panel?	Typical stakeholders
	Level of expertise	How is the level of expertise approved?	Not specified
Delphi-Anonymity	Anonymity	Is the whole Delphi process anonymous? If not, where is it weakened?	Not specified
Delphi-Questionnaire	Questionnaire origin	Where does the questionnaire input come from?	Deskwork; expert interviews
	Open-ended questions	Are open-ended, closed questions or both posed?	Open-ended
	Focus of queries	What is the focal point the questions?	Probability; desirability
	Medium	How is the questionnaire transmitted to the participants?	Not specified
	Possibility to comment	Do the participants have the possibility to comment and complete their questionnaires?	Yes
Delphi-Feedback	Feedback to experts	Is feedback send back to the participants?	Yes
	Type of report to the experts	What kind of feedback is send back to the participants?	Preliminary scenarios
	Consideration of comments	Are the questionnaires modified based on the comments?	Yes
	Explanatory statements	Can the participants (have to) explain their opinion if it differs from the majority?	Yes (possibility)
	Possibility to revise the opinion	Do the participants have the possibility to revise their opinion?	Yes
	Statistical group response	Is a statistical group response provided? If yes, which?	Yes, quantile–quantile plot, frequencies, mean , median, standard deviation

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Theatre & Dance database. By applying the search terms "scenario" and "delphi" to abstract, title, or topic, we identified 362 studies. We completed the list with searches of Web of Science and Google Scholar as well as journal specific searches of Futures, Long Range Planning, and Technological Forecasting and Social Change (TFS), which are the "*home journals*" [17] of scenario planning, foresight methods and the Delphi technique.

We cleared the dataset of duplicates. Then we excluded purely methodological papers (e.g., Martino [18]) because our review focuses on empirical studies that integrate the Delphi technique within scenario planning. Moreover, we excluded studies that use the word scenario but do not have a clear foresight perspective as was the case with most of the medical studies, e.g., Endacott et al. [19]. We identified fifteen studies that primarily focus on the Delphi technique and use the term scenario in a rather colloquial manner as a synonym for Delphi theses. We categorized these studies as pure Delphi studies and excluded them from our analysis. Furthermore, studies were excluded that did not provide sufficient information about the application of one of the methodologies of interest. For example, Pätäri [20] mentions the inclusion of future scenarios within the third round of the Delphi process but fails to describe the scenarios in any further detail. In the end, we yielded a total set of 24 Delphi-based scenario studies to be included in our review. See Table 2 for an overview of the studies included in the review.

We analyzed the Delphi-based scenario studies by developing a coding scheme. To ensure reliability and validity of our review, we followed Fink's [15] proposition of conducting a pilot test. The coding team was trained, and a pretest of the coding scheme was conducted with ten studies. The coding scheme was modified and consolidated in accordance with the results of the pilot test. Following the rules of a content analysis, the coding scheme and its categories and subcategories (see Table 1) were subsequently deducted from the key design options of scenario planning and the Delphi technique as presented in Sections 3.1 and 3.2. as well as the different combination possibilities. In Table 1, we provide an example of coding for one study.

The results of the review are presented and discussed in the combined results and discussion Section 4. Finally, by bringing together the results of the review with the background worked out in Section 3, we will offer recommendations on how a Delphi-based scenario study should be designed to ensure the highest possible degree of quality. This will be summarized in the concluding section of the paper.

3. Methodological considerations

3.1. Key design options of scenario planning

The wide range of potential and actual applications of scenario planning adds to the confusion over the various ways of defining related terms. The term scenario, for example, has numerous definitions [10,13,21,22]; however, for our purposes, we have adopted the definition of the Intergovernmental Panel on Climate Change (IPCC): "*A scenario is a coherent, internally consistent and plausible description of a possible future state [of the analyzed system][…]. It is not a forecast; rather, each scenario is one alternative image of how the future can unfold. A projection may serve as the raw material for a scenario, but scenarios often require additional information (e.g., about baseline conditions). A set of scenarios is often adopted to reflect, as well as possible, the range of uncertainty in projections.*" [23].

3.1.1. Key design elements of scenario planning

3.1.1.1. Scenario goal. Several authors categorize and synthesize the various types of scenarios [11,12,24]. Börjesson et al. [11] differentiate the scenarios, and, based on their goal, they distinguish between predictive, explorative and normative scenarios. Predictive scenarios are short-term oriented and seek to answer the question "*What will happen?*" The main objective of predictive scenarios is to clarify how specific drivers will develop. Explorative scenarios aim to answer the question "*What can happen?*" They focus on the identification of drivers and are frequently developed on the basis of rather qualitative information. Normative scenarios assess how a specific target can be reached. We argue that this categorization is inconsistent because normative aspects can be integrated either in predictive or in explorative scenarios in the scenario transfer phase of scenario planning (see Section 3.1.2).[1] Therefore, we exclude normative scenarios as a category from our analysis.

3.1.1.2. Range of future states. The main characteristic of scenario planning is its ability to capture a broad range of possible future states by identifying trends and uncertainties. Developing a set of scenarios encourages decision makers to consider alternative futures rather than to assume fixed circumstances [25]. The rationale for using scenarios is that some systems and their driving forces are too complex to be modeled and predicted with certainty, even with improved models and increased resources [23,26]. Illustrating the uncertainty in a set of scenarios allows the planner to take it into account each decision. Thus, "*…the objective of scenario planning is to generate a set of scenarios that collectively bound the perceived range of possible futures*" [27]. This is comparable to preparing for a hiking tour in the mountains. One cannot know what the weather conditions will be; thus, one must pack sunglasses, a raincoat, and a full set of winter equipment.

As a consequence, the number of scenarios needed to sufficiently plot the range of possible futures is an important design decision. Developing only one scenario would constitute a prediction,[2] which is contradictory to the philosophy of scenario

[1] This can be easily done in the scenario transfer phase in which a preferred future can be chosen.

[2] One exception is a backcasting exercise in which preliminary scenarios are used and the scenario transfer is the main focus of the exercise. For such a backcasting exercise one illustrative scenario might be sufficient. For example, the following scenario: *"Imagine! Peking with ten times more inhabitants than today but with the same amount of water and energy resources! What are the consequences for the lifestyle, water and energy management?*

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planning, that is, to span a room of uncertainty. While "*sometimes two scenarios are sufficient to bind this zone of possibilities*" [28], most scenario planning studies suggest there be three or four scenarios [26].

3.1.1.3. Scenario logic and presentation. The range of possible futures is determined by the differences between the scenarios. A set of scenarios should be developed using a certain logic and will ensure, therefore, internal consistency. A frequently used scenario logic is the matrix-logic. An illustrative example for this matrix-logic is the Millennium Ecosystem Assessment [29] or the Intergovernmental Panel on Climate Change (IPCC) [23]. An alternative scenario-logic is one applied by Marcus [30] that is based on a perspective-logic. The distinctive feature of these scenarios is the different points of view, which are adapted to the drama genres of romance, tragedy and comedy,[3] from which the scenarios are presented.

The possibility of dealing with unforeseeable events such as terrorist attacks or pandemics (so-called wildcards), weak signals, external shocks, or discontinuities is one of the main features of scenario planning. These unexpected events may have probabilities of nearly zero, but if they do occur, they likely have an extremely high impact. These discontinuities can be accounted for in scenario planning studies intended to enrich the scenario development by "*thinking the unthinkable*" [33].

Often scenarios are designated as "*business as usual*", "*worst case*" or "*best case*". While this can be a good starting point, it must be implemented carefully. Sometimes scenarios are labeled "*most probable*" or "*most unlikely*". The latter two scenarios reflect highly subjective probability calculations. In such cases, the scenario planner risks encouraging the decision maker to focus only on the most probable scenario while ignoring scenarios that would foil efforts to illustrate the full range of uncertainty. As determined by Goodwin and Wright [27], Schnaars [26] and Millet [22], subjective probabilities of most probable scenarios can lead to psychological biases. This has been widely researched and documented by other scholars [31,32].

3.1.2. Generic scenario approach

Scenarios should be embedded in a broader decision-making context. The process of scenario planning serves this function: it includes the processes of developing scenarios and transferring the findings for the purpose of decision-making. The scenario planning process, that is, the actual steps taken during a scenario planning project, should reflect this function. In the recent literature, each author has his own approach and designates the steps to his preference. In addition, the number of steps involved varies considerably (e.g., four steps in Phelps et al. [34] and ten steps in Linneman and Kenell [35]). Our argument is built upon the generic foresight approach of Bishop et al. [24], who use six steps for a complete scenario planning study and include the two main phases of scenario planning: scenario development (step 1–3) and scenario transfer (step 4–6). In the scenario development phase, the scenarist visualizes different states of the future; in the scenario transfer phase, the consequences for today's decisions are derived. [36].

The generic scenario process consists of the following steps:

I. Scenario development
   1. Framing: The purpose of this step is to shape the project according to the attitude of the audience, the work environment, the rationale, the purpose, the objectives, and the teams. The outcome of this step is a project plan.
   2. Scanning: Here all relevant information about the system, history and context of the issue is collected. The product, at the end of this step, is information about trends and drivers.
   3. Forecasting: This step identifies the key drivers and uncertainties and it integrates them in a systematic manner within the scenarios. The scenarios clarify the implications and outcomes.

II. Scenario transfer
   4. Visioning: In the visioning phase, a strategy has to be worked out with respect to how to deal with future challenges. Based on the scenarios, the consequences for today's decisions have to be drawn. Alternatively, a preferred future can be developed as well as a strategy on how this future can be reached. In this step, normative aspects can be integrated. Depending on the strategy, goals must be set and performance measures must be defined.
   5. Implementing: The necessary resources must be organized, and the plan must be implemented and communicated.
   6. Controlling[4]: Once the plan is implemented, fulfillment of the goals must be evaluated continuously. Furthermore, this process should be iterative; if new information about the future becomes available or new challenges arise, the scenario development should be repeated.

In our coding scheme (see Table 1), scenario planning is considered in four subcategories: scenario goal, range of future states, scenario logic and presentation of scenarios.

3.2. Key design options of the Delphi technique

The Delphi technique, which is the main topic of this special issue,[5] is defined by Linestone and Turoff [37] as "*a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem.*"

[3] Other scenario logics or "archetypes" as cited in Alcamo [54] can be found in van Asselt et al. [86] and Tibbs [87].
[4] This step differs from the generic scenario approach of Bishop et al. [24]. The original name of this step was "acting".
[5] Even if the Delphi technique is the main topic of this special issue, we have to elaborate on the method to deduct the coding categories for our review.

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3.2.1. Key design elements of the Delphi technique

The key design elements of the Delphi technique are anonymity, iteration, controlled feedback and participating experts[6] [5,6,37]. In most Delphi studies (as identified in Gupta and Clarke [3] and Landeta [5]), a number of experts is each given an anonymous questionnaire to answer questions concerning their field of expertise.

The most important argument for anonymity is the possibility to avoid negative impacts of group communication processes similar to the "*Bandwagon effect*" [38]. In Delphi studies, controlled feedback is provided to the experts in the form of quotes, summaries, median or mean statistics. The experts are then asked to comment on the responses of the other experts, defend their own positions, develop new ideas and/or answer new questions introduced by the monitoring team. The results are often presented as a statistical group response.

Iteration is especially important if the main purpose of the Delphi technique is to seek consensus as is the case in the *Classical Delphi*. The *Classical Delphi* is similar to the Delphi studies that were prepared by the RAND Cooperation, and it has been subject to severe criticism since the late 70's [39–41]. Due to the criticism, some modifications of the Delphi technique have been suggested [42]. The *Policy Delphi* proposed by Turoff [43] seeks opposing views on the topic at hand. Kuusi and Meyer [44] further developed the *Policy Delphi* into the *Argument Delphi* in which the arguments, collected in the precedent Delphi questionnaire, are further discussed in groups. Tapio [42] as well as Rikkonen and Tapio [45] use a cluster analysis in their *Disaggregative Policy Delphi* as a basis for the development of the scenarios.

Further adaptations of the Delphi technique affect the iteration and feedback. In a Real Time Delphi [17,46], the use of the Internet and corresponding programming allows immediate feedback after the experts have answered the questionnaire via web-based applications. Other experts are, thus, able to respond, comment, or argue immediately, which allows direct feedback and almost infinite iteration.

3.2.2. Key functions of the Delphi technique

Häder and Häder [47] differentiate between two main functions concerning the general character of the Delphi technique: *idea-generation* and *judgment function*. In a pure idea-generation Delphi, the main objective is to identify a broad range of possible views on a specific topic. The monitoring team mainly serves a moderating function and sends out open-ended questions to the experts. The idea-generation function is typically used in a Policy Delphi.

In a pure judgment Delphi, the monitoring team has greater responsibility because it must select and formulate items that will be evaluated by the experts; in a pure idea-generation Delphi, this task is explicitly delegated to the experts. The questions are formulated in a closed manner and the importance, impact, time of occurrence, and the probability of occurrence of an event are all evaluated by the experts. Pure judgment Delphi studies correspond to Classical Delphi studies.

Okoli and Pawlowski [48], based on Schmidt et al. [49], add a third function. They present three main process steps that reflect the functions of Häder and Häder [47]: brainstorming, narrowing down, and ranking. Whereas brainstorming and ranking correspond to the idea-generation function and the judgment function, respectively, the narrowing down phase describes an additional function. Idea-generation Delphi studies, which also include an evaluation of the identified items, must consolidate the range of ideas. This is often done by asking the experts to evaluate the importance of the identified items. We name this function *consolidation function* and use it together with the *idea-generation function* and *judgment function*.

We have made each of these design options of the Delphi technique a category in our coding scheme (see Table 1).

3.3. Evaluation of combination possibilities of scenario planning and the Delphi technique

We now assess the incorporation of the Delphi technique into scenario planning. We show into which steps of the generic scenario planning process each Delphi function can be integrated. A combination of the two methods is only recommended if it improves the quality of the scenarios. To evaluate the quality, we develop scenario specific quality criteria derived from general scientific quality criteria.

Several authors [25,50–54] discuss quality criteria for scenarios that consider the special characteristics of scenarios. Schoemaker [25,51,55] and Alcamo [54] emphasize the particularity of scenarios and the importance of creativity within scenario planning. We propose to consider the creative aspect of scenario planning and to assess the "scientific effort" using general scientific quality criteria based on Miles and Huberman [56]. Our quality criteria for scenarios consist of the five criteria: objectivity, credibility, legitimacy, transferability and creativity. Objectivity refers to possible biases caused by the researcher. Credibility summarizes the scientific quality standards of internal validity and reliability, which can be ensured by a triangulation of methods and data. Transferability, in the sense of external validity, assesses the relevance of the scenarios in a broader context. Legitimacy evaluates scenarios from the perspective of the actual users, such as politicians or strategic planners. Creativity judges the innovativeness and stimulant effect of the scenarios [57]. In the following, we use creativity, objectivity, and credibility to assess the quality of Delphi-based scenarios because these criteria depend on established methods and can be assessed for published articles.

[6] The participating experts are not mentioned in the usual enumeration of Delphi elements, but they are necessary as constituting elements of a group.

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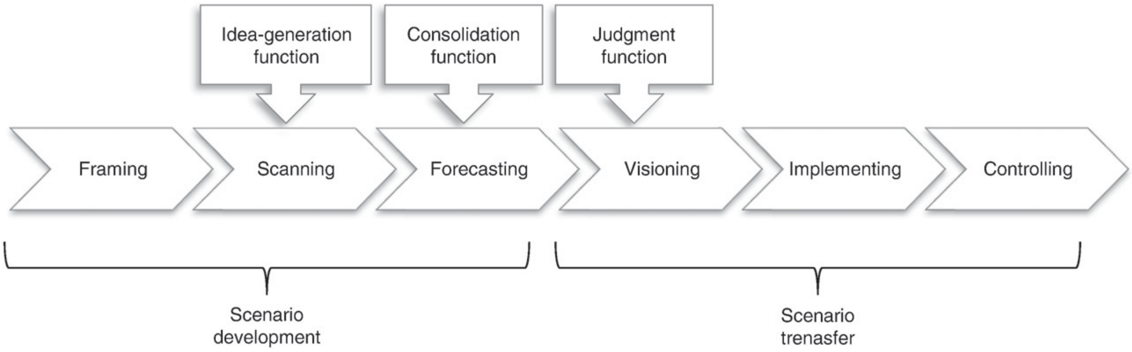

Fig. 1. Integration of the Delphi function within the generic scenario planning approach.

Based on key functions of the Delphi technique and the generic scenario planning approach presented above, we now propose potential combinations[7] of the two methods to answer the first research question: How can the Delphi technique enhance the quality of a scenario study? We answer the question in terms of the derived criteria: creativity, credibility and objectivity. We identified three steps in the generic scenario approach in which the integration of the Delphi functions is fruitful. See also Fig. 1.

3.3.1. Scanning phase

Experts can be incorporated into the scanning phase of scenario planning so that they may identify possible future trends and challenges via the idea-generation function of the Delphi technique. This combination of the two methods allows increased *creativity* by diversifying perspectives on the issue. The scenarist can use a significantly larger reservoir of ideas. Anonymity facilitates the disclosure of weak signals and helps to identify discontinuities and to overcome threats of ineffective communication processes. Furthermore, in later Delphi rounds, the experts can further develop and solidify their ideas as well as incorporate the ideas of the other experts based on iteration and feedback. *Objectivity* generally increases by integrating the idea-generation function into the scanning phase because the identification of possible future trends and drivers is not conducted behind closed doors but rather is based on broad independent expert knowledge. The possibility of ignoring important drivers is reduced because the responsibility is distributed among several people, thus increasing *credibility*.

3.3.2. Forecasting

In the forecasting phase of scenario planning, drivers and uncertainties must be evaluated and those drivers to be included in further analysis must be selected. Experts can assist the scenario planner by employing the consolidation function of the Delphi technique in this phase.[8]

In this combination, *creativity* and *credibility* play a minor role. The main function of the experts is to reduce the number of trends and prioritize the drivers. However, *objectivity* increases because the evaluation of the drivers is no longer dependent on the researcher.

3.3.3. Visioning

In the visioning phase of the scenario approach, the consequences for today's decisions must be derived. Once a set of scenarios is prepared, experts can be invited to evaluate the scenarios as to their desirability and to propose possible strategies or adaptation options via the judgment function of the Delphi technique. If the identification of possible adaptation options is of prime importance, the judgment function resembles the idea-generation function seeking creative input from the participating experts.[9] *Creativity* benefits because the scenario process benefits from a greater input of ideas by the experts. *Objectivity* increases by eliminating the possibility of biases on the part of the researchers, whose importance is reduced by relying on the expert's opinion. *Credibility* increases because the danger of omitting relevant adoption options is reduced.

Thus, the integration of the Delphi technique within a scenario study is especially reasonable in the scanning phase of scenario planning via the idea-generation function of the Delphi technique and in the visioning phase via the judgment function because the combinations increase creativity, credibility and objectivity. In the forecasting phase, a combination of the two methods mainly increases objectivity.

[7] Delphi functions can be integrated in scenario planning studies (Delphi-based scenarios) and scenarios can be integrated into the Delphi technique (scenario-based Delphi). We focus on Delphi-based scenarios. Generally, one could argue that we ignore scenario-based Delphis. There are two possibilities for integrating scenarios in the Delphi technique. The first is that previously prepared scenarios are evaluated by the Delphi technique. The second is that results are presented as scenarios. The first possibility is a Backcasting Delphi, and the second possibility falls within the idea-generation and the consolidation function. Therefore, we focus on the Delphi-based scenario categorization.

[8] Another way to evaluate and select the key drivers and uncertainties is to employ the Cross-Impact Analysis [32,34,46,62,63]. Experts can also supply the input required for the Cross-Impact Analysis. The authors assume that this is frequently outsourced to a monitoring or steering team to minimize the workload for the experts.

[9] The visioning phase can also be applied alone if some scenarios are prepared in advance and the expert is encouraged to focus on identifying and evaluating possible adaption options. Börjesson et al. [32] designate this combination of scenarios and the Delphi technique as Backcasting Delphi.

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4. Systematic research review

After showing that a combination of the two methods can, in general, enhance the quality of scenarios in terms of creativity, objectivity and credibility, we now turn two the second research question: What is the span of possible design options in the existing body of Delphi-based scenario studies? We will present the results and discuss possible recommendations.

As stated in the methodological section, our sample consists of 24 studies. The most important journal for the publication, with seven articles on Delphi-based scenario studies, is the journal of this special issue, Technological Forecasting and Social Change. The results show a relatively constant number of published Delphi-based scenario studies over time with an exceptionally high number (6) of publications in 2009. The analysis of the thematic scope reveals a remarkably high number (7) of studies concerned with the future of transportation. The local scope of half of the studies is concentrated in Europe. Further descriptive results can be found in Table 2.

The low number of publications, in our view, is due to the complexity of foresight studies and the fact that the Delphi-based scenario studies are underestimated. In our sample, four studies [42,58–60] explicitly mentioned during the research process that an adaptation of the originally planned research design was necessary. As a consequence, some authors might refrain from publishing their Delphi-based scenario studies due to the complexity, or they may opt to publish it in parts.

4.1. Key elements of scenario planning

The predominant goal of the 24 Delphi-based scenario studies is of an explorative nature (18). Six studies have a predictive focus and are, thus, interested in concrete values of specific drivers rather than identifying trends. The time span considered in the studies varies between eight and 53 years with a median time span of 21 years and an average of 22.9. As illustrated in Fig. 2, explorative scenario studies consider a longer time span. On average, they consider a time span of 26.4 years (median = 22) whereas predictive scenario studies span 15.5 years (median = 11).

The differentiation between the predictive and explorative scenario studies of Börjesson et al. [11] turned out to be an appropriate categorization for scenarios. In view of the results (see also Fig. 2), predictive scenarios are not only quantitative but also short-term oriented, whereas explorative scenarios are qualitative and long-term oriented.

The number of scenarios varies between one [62] and fifteen [71], with 18 studies using at least two scenarios. Three scenario studies [62,66,79] develop only one scenario, and three studies [42,60,64] do not specify the number of scenarios.

We underlined the importance of using more than one scenario to achieve meaningful scenario planning in Section 3.1.1. The absolute minimum should be two scenarios; however, the number of scenarios should be chosen in consideration of the underlying scenario logic.

Table 2
Scope of the Delphi-based scenario studies.

No.	Name	Year	Journal	Regional focus	Thematic focus	Ref.
1.	Abadie et al.	2010	Sci. Public Pol.	Europe	Creative content industries	[58]
2.	Al-Saleh	2009	Futures	Saudi Arabia	Renewable energy scenarios	[61]
3.	Ariel	1989	Marit. Policy Manage.	Global	Shipping industry	[62]
4.	Bijl	1992	Futures	Netherlands	Mental health care	[63]
5.	Czaplicka-Kolarz et al.	2009	TFS	Poland	Energy sector	[64]
6.	Eschenbach & Geistauts	1985	Interfaces	Alaska	Trends of Alaskan economy	[65]
7.	Fleming	1979	Long Range Plann.	US	Government-corporate relations	[66]
8.	Gómez-Limón et al.	2009	Futures	Spanish region	Agricultural sector	[67]
9.	Gordon	2007	Foresight	Global	Energy	[68]
10.	Höjer	1998	Transport. Res.	Global	Telematics in urban transport	[69]
11.	Hupkes	1974	Transportation	Netherlands	Automobile	[59]
12.	Kropp	2003	J. Euromarket.	North America and EU	Values in marketing	[70]
13.	Pal et al.	2009	Int. J. Appl. Eng. Res.	India	Public transport	[60]
14.	Postma et al.	2007	TFS	Netherlands	Medical technology	[71]
15.	Rikkonen and Tapio	2009	TFS	Finland	Bioenergy	[45]
16.	Shiftan et al.	2003	Transport. Res.	Tel-Aviv	Transport systems	[72]
17.	Svidén	1988	TFS	Not specified	Transport systems	[73]
18.	Tapio	2002	TFS	Finland	Transport policy	[42]
19.	Tseng et al.	2009	TFS	Global	TV market	[74]
20.	Volman	2005	Teaching a. Teacher Edu.	Netherland	Education	[75]
21.	Von der Gracht and Darkow	2010	Int. J. Prod. Econ.	Germany	Logistics service	[76]
22.	Waissbluth and de Gortari	1990	TFS	Mexico	Agro industry	[77]
23.	Wilenius and Tirkkonen	1997	Futures	Finland	Climate policy	[78]
24.	Zuber et al.	1996	Soc. Prev. Med.	Switzerland	Health care	[79]

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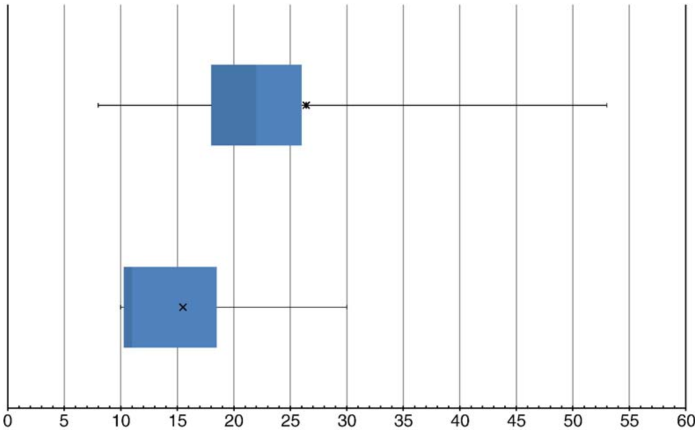

Fig. 2. Box–Whisker plots of the considered time span.

The scenario logic applied in the studies of our sample is based on different approaches. Most of the studies are developed around the key drivers, that is, variations between the key drivers determine the differences between the scenarios. In three Delphi-based scenario studies [66,71,80], time constitutes one of the possible dimensions; thus, the development over time of specific drivers are illustrated. In this special case, we would prefer technology roadmapping [81] as a more appropriate method. A few studies [60,63,72,73,76] are based on probabilities of occurrence (most probable scenario) combined, in some cases, with additional scenarios. For example, von der Gracht and Darkow [76] develop scenarios that are based on the most probable future in addition to some wildcard scenarios. We have previously discussed the difficulties of this scenario logic in Section 3.1.1.

The presentations of the scenarios vary according to the underlying scenario logic between the presentation of pure quantitative data, scenario sketches and complete storylines. Discontinuities or wildcards play a surprisingly minor role. Only six studies [61,63,66,69,70,76] considered this special feature within their scenario development.

Table 3
Delphi function and scenario goal of Delphi-based scenarios.

Name	Year	Idea-generation (1 = yes)	Consolidation (1 = yes)	Judgment (1 = yes)	Explorative scenarios (1), predictive scenarios (0)
Abadie et al.	2010	1	1		1
Al-Saleh	2009	1		1	1
Ariel	1989	1	1	1	0
Bijl	1992	1		1	1
Czaplicka-Kolarz et al.	2009			1	1
Eschenbach and Geistauts	1985			1	1
Fleming	1979			1	1
Gomez-Limon et al.	2009			1	0
Gordon	2007			1	1
Höjer	1998			1	1
Hupkes	1974			1	1
Kropp	2003			1	1
Pal et al.	2009			1	0
Postma et al.	2007	1	1	1	1
Rikkonen and Tapio	2009	1	1	1	1
Shiftan et al.	2003	1	1	1	0
Svidén	1988	1		1	1
Tapio	2002	1		1	1
Tseng et al.	2009		1	1	0
Volman	2005	1	1	1	1
Von der Gracht and Darkow	2010		1	1	1
Waissbluth and de Gortari	1990		1	1	0
Wilenius and Tirkkonen	1997	1	1	1	1
Zuber et al.	1996			1	1
Total		11	10	23	6 pred. + 18 explor.

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4.2. Combination possibilities

In the identified Delphi-based scenario studies, the most often used Delphi function was the judgment function. This function is also the only separately used function, while the idea generation function and the consolidation function were, in most cases, used in combination with at least one other function.

All predictive studies use at least the judgment function. Predictive scenario studies concentrate on the consolidation and judgment function of the Delphi technique. Thus, they get support by the Delphi technique for the evaluation of already identified drivers.

In explorative scenario studies, the judgment function is considered very important. Those explorative studies that do not rely on the judgment function focus on the idea-generation function of the Delphi technique. In both cases, they seek creative input from the experts for possible future trends or possible adaptation options. See also Table 3.

Based on these results, we recommend scenario planners with explorative objectives and more long-term perspectives to use the idea-generation function of the Delphi technique. For predictive and more short-term oriented scenario studies, we recommend using the judgment function and combining it, if necessary, with the consolidation function.

4.3. Key elements of the Delphi technique

4.3.1. Iteration

The majority (16) of the identified studies conducted two Delphi rounds. Five studies conducted a third round and only one [78] conducted a fourth Delphi round. Abadie et al. [58] and Gordon [68] conducted Real Time Delphi studies.

We recommend choosing the number of Delphi rounds based on the study design. Furthermore, the number of functions that the Delphi technique has to fulfill within the scenario study and the necessity for feedback should be considered.

4.3.2. Participating experts

Researchers invited, on average, 4.4 times more experts than actually participated in the first Delphi round. The average dropout rate after the first round was 18%. After the second round, some studies were able to increase the number of participating experts leading to an average dropout rate of −4% (see also Table 4).

Table 4
Number of rounds and dropout rates in the Delphi-based scenario studies.

Name	Year	Number of rounds	Number of invitations	Number of experts in round 1	Number of experts in round 2	Number of experts in round 3	Dropout rate after round 1	Dropout rate after round 2
Abadie et al.	2010	RT	1111	288	124		57%	
Al-Saleh	2009	3	35	33	27	32	18%	−19%
Ariel	1989	3	109	59	55	52	7%	5%
Bijl	1992	2	104	86	88		−2%	
Czaplicka-Kolarz et al.	2009	2	750	n. s.	275			
Eschenbach and Geistauts	1985	3	152	91	n. s.	n. s.		
Fleming	1979	3	20	21	22	23	−5%	−5%
Gómez-Limón et al.	2009	2	n. s.	n. s.	n. s.			
Gordon	2007	RT	125	13	n. s.			
Höjer	1998	2	310	86	65		24%	
Hupkes	1974	2	906	53	56		−6%	
Kropp	2003	2	175	62	54		13%	
Pal et al.	2009	2	300	138	36 [a]		74%	
Postma et al.	2007	2	n. s.	35	35		0%	
Rikkonen and Tapio	2009	2	n. s.	18	20		−11%	
Shiftan et al.	2003	2	63	28	18		36%	
Svidén	1988	2	120	54	31		43%	
Tapio	2002	2	n. s.	n. s.	n. s.			
Tseng et al.	2009	2	n. s.	13	10		23%	
Volman	2005	2	13	10	13		−30%	
Von der Gracht and Darkow	2010	2	72	30	30		0%	
Waissbluth and de Gortari	1990	2	n. s.	6	12			
Wilenius and Tirkkonen	1997	4	142	98	20	20 [b]	80%	0%
Zuber et al.	1996	3	n. s.	30	30	30	0%	0%
Min		2	13	6	10	20	−0,3	−19%
Quartile (25%)		2	72	21	20	23	−2%	−5%
Median		2	125	35	31	30	10%	0%
Quartile (75%)		3	300	86	55	32	33%	0%
Max		4	1111	288	275	52	80%	5%
Average		2.3	265	60	51	31	18%	−4%

n. s.: not specified.
RT: Real Time Delphi.
[a] Experts excluded by the monitoring team.
[b] In a fourth round 20 experts participated.

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The number of experts should also be chosen with regard to the study design. In a Real Time Delphi, the number of experts can be much larger, whereas, in studies that rely on expert interviews, this number may be much lower due to practical reasons.

Of the 24 studies, 14 do not specify how they evaluated the level of expertise of the participating experts. In these studies, it is questionable whether it is still legitimate to designate the participants as experts. Of those studies that mention their experts' qualifications, descriptions vary considerably between the number of articles published, years of work experience, position, regional provenience and stakeholder status. If studies include two or more criteria that reflect different aspects of expertise, we define it as multi-perspective criteria. Four studies evaluate the level of expertise by using a self-assessment in their questionnaire. Of these four studies, one study combines [63] the self-assessment with multi-perspective criteria. Multi-perspective criteria (5) and self-assessment (3) are the most prevalent expert evaluation criteria. We argue that self-assessment of the experts might be problematic in the case of open-ended questions. In this case, multi-perspective criteria for the expert selection is more appropriate. The criteria should be as flexible as necessary; however, it needs to be explicitly and honestly mentioned in the study.

4.3.3. Anonymity

Anonymity during the entire process is ensured in 14 of the 24 studies. In five studies, anonymity is attenuated. For example, in the study of Gómez-Limón et al. [82], the second Delphi round is held as a seminar in a workshop round. Five studies do not provide any information whether anonymity has been ensured.

In the presence of the *Bandwagon effect* or other disturbing effects, anonymity is definitely important, but we prefer adopting a more flexible standard of anonymity. After a first anonymous round, which could also be conducted as expert interviews, a workshop can facilitate "*creative synthesis*" in which two former unrelated ideas of different experts are combined [83]. This would also reduce the number of Delphi rounds that would otherwise be necessary.

4.3.4. Questionnaire

The questionnaire input varies from pure desk work to a combination of several methods. In some cases, expert interviews provide the basis for the formulation of the questionnaires. In other cases the questionnaire is based on the PESTEL framework[10] and Porter's five forces [84,85]. Pre-surveys are employed by Ariel [62], Kropp [70], von der Gracht and Darkow [76]. Kropp [70], Hupkes [59], Höjer [69] and Bijl [63] use previously developed scenarios. The majority of studies rely on a single source for the questionnaire whereas others (5) based their input on several sources. With respect to triangulation, the combination of several input sources for the questionnaire is recommended.

The formulation of the questions varies as well. In four cases, the questions are closed-ended. In another five studies, the questions are closed-ended, but the participating experts were allowed to add comments. In nine studies, an open-ended questionnaire design was chosen. Six studies apply closed-ended questions in addition to open-ended questions. Questions focus on timing, probability, plausibility, feasibility, desirability and the importance of occurrence, possible courses of action, impacts, costs and barriers.

We suggest using open-ended questions if the Delphi technique mainly serves as a source of creative input for the idea-generation function. If the Delphi technique is used for judgment purposes, it depends on the extent of creativity needed, and open-ended questions are recommended. If the collection of adaptation options or the evaluation of the scenario in terms of desirability, plausibility or feasibility is the main purpose, then close-ended questions are most appropriate. For the consolidation function, the use of closed-ended question is suggested.

4.3.5. Feedback

Only one study [59] sent no feedback to the participating experts in between the Delphi rounds. The majority (17) of the studies explicitly mention that they give feedback. In the two Real Time Delphi studies [58,68], the feedback is given via a web application. Four studies do not explicitly mention feedback. When feedback is permitted, it is organized in various forms. The majority of the studies provide statistics in the form of median values, mean values, or quartiles. In some cases, preliminary scenarios are sent back to the participating experts. In other cases, rankings, modal scores, or aggregated arguments or quotes are used as feedback. Von der Gracht and Darkow [76] conducted a summarizing content analysis to synthesize the arguments of the experts.

Feedback plays an important role when the creative synthesis is in the foreground. Thus, the generation of ideas is based on the input of other participating experts. This is usually the case for the idea-generation function and, in some cases, also for the judgment function of the Delphi technique. In these cases, the scenarist should take care that the information flow from one expert to the next expert is ensured. Therefore, the feedback should consist of more than mean or median statistics. Synthesized arguments and ideas are more appropriate.

This chapter has shown that the span of possible design options in the existing body of Delphi-based scenario studies vary considerably. Some studies applied our recommendations to a very high degree, whereas others do not even specify design options in appropriate depth.

[10] PESTEL stands for the scanning of the political, economic, social, technological, and legal framework conditions [88,89].

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5. Conclusions

Based on the findings of the methodological literature as well as the findings of the integrated results and discussion chapter, we will now conclude how quality in terms of creativity, credibility and objectivity in future Delphi-based scenario studies can be ensured.

Scenario planners need to be aware of the goal of their scenario study, whether they want to identify possible challenges and drivers in explorative scenario studies or whether they want to specify the impacts of already known drivers in predictive scenario studies. In explorative scenario studies, we see the added value in the ability of the Delphi technique to capture creative input, identifying future challenges or adaptation options in the scanning or visioning phase of the scenario approach. In predictive scenario studies, the focus should be on the judgment function of the Delphi technique, which is primarily useful in the visioning phase, whereas the integration of the Delphi technique within the forecasting phase should be considered carefully. In order not to overcharge the experts, the identification of the key drivers should be delegated to a panel.

The quality in terms of *creativity* of Delphi-based scenarios studies can be ensured by integrating the idea-generation function of the Delphi technique into the scanning phase. If disturbing effects, such as the *Bandwagon effect*, are obstacles to an effective group communication, we recommend attaching importance to anonymity. *Creativity* profits as well in the visioning phase (if adaptation options are to be identified) especially by the larger reservoir of ideas generated by the integration of the experts. Especially promising is the identification of weak signals. One researcher on his own might be overstrained, but by having a considerably larger reservoir of ideas, weak signals might be identified that otherwise would have gone unnoticed. If creative input is needed, some design options need to be especially aligned for capturing the ideas of the experts. The process should be as open as possible. Open-ended questions give the experts the possibility to develop ideas, to have a sufficiently high number of Delphi-rounds and to provide feedback that allows the experts to better understand the thoughts and ideas of the other experts as necessary. If experts have the possibility to comment then the responsible facilitator must ensure that these comments are incorporated into the next Delphi round. Expert interviews and, in later rounds, workshops can serve as a complementing feature. The use of the most probable scenario should be avoided because it might limit the decision-maker from capturing the full creative input of the scenarios.

The integration of the Delphi technique in the three scenario phases increases *objectivity* because the responsibility of the researcher is distributed among the experts. Therefore, the expert selection must not be biased. Biases in the questionnaire design can lead to results that depend on the researcher rather than on the opinion of the experts. Therefore, we recommend using a neutral framework for the questionnaire design and selecting the experts carefully. For idea-generation, the PESTEL framework is a good starting point.

The *credibility* of scenarios benefits from the integration of the Delphi technique because experts ameliorate the completeness of scenarios in the scanning and visioning phases. Therefore, the role of weak signals and discontinuities has to be explicitly determined. Possible biases mentioned earlier also affect the credibility. In general, triangulation should be considered in each design decision of a Delphi-based scenario study. The design decisions have to be well justified and explained and should be documented in such a way that the study is replicable.

In general, we recommend integrating the Delphi technique within a scenario study. In view of the complexity of foresight studies, we strongly recommend focusing on the integration of the Delphi technique in only one phase of the scenario approach. In this way, the design options can be intentionally adjusted to the particular function.

References

[1] P. Bishop, A. Hines, T. Collins, The current state of scenario development: an overview of techniques, Foresight 9 (1) (2007) 5–25.
[2] B. MacKay, P. McKiernan, Creativity and dysfunction in strategic processes: the case of scenario planning, Futures 42 (4) (2010) 271–281.
[3] U.G. Gupta, R.E. Clarke, Theory and applications of the Delphi technique: a bibliography (1975–1994), Technol. Forecast. Soc. Change. 53 (2) (1996) 185–211.
[4] J.F. Preble, Public sector use of the Delphi technique, Technol. Forecast. Soc. Change. 23 (1) (1983) 75–88.
[5] J. Landeta, Current validity of the Delphi method in social sciences, Technol. Forecast. Soc. Change. 73 (5) (2006) 467–482.
[6] G. Rowe, G. Wright, The Delphi technique as a forecasting tool: issues and analysis, Int. J. Forecast. 15 (4) (1999) 353–375.
[7] F. Woudenberg, An evaluation of Delphi, Technol. Forecast. Soc. Change. 40 (2) (1991) 131–150.
[8] T.J. Chermack, S.A. Lynham, W.E.A. Ruona, A review of scenario planning literature, Futures Res. Quart. 17 (2) (2001) 7–32.
[9] P. Cornelius, M. Romani, A. Van De Putte, Three decades of scenario planning in shell, Calif. Manage. Rev. 48 (1) (2005) 95–109.
[10] R. Bradfield, G. Wright, G. Burt, G. Cairns, K. Van Der Heijden, The origins and evolution of scenario techniques in long range business planning, Futures 37 (8) (2005) 795–812.
[11] L. Börjeson, M. Höjer, K. Dreborg, T. Ekvall, G. Finnveden, Scenario types and techniques: towards a user's guide, Futures 38 (7) (2006) 723–739.
[12] P.W.F. van Notten, J. Rotmans, M.B.A. van Asselt, D.S. Rothman, An updated scenario typology, Futures 35 (5) (2003) 423–443.
[13] C.A. Varum, C. Melo, Directions in scenario planning literature – a review of the past decades, Futures 42 (4) (2010) 355–369.
[14] H.M. Cooper, Synthesizing research: a guide for literature reviews, 3.th ed, Sage Publications, Inc, Thousand Oaks, London, New Delhi, 1998, p. 216.
[15] A. Fink, Conducting research literature reviews: from paper to the Internet, 3.th ed, Sage Publications, Los Angeles, London, New Delhi, Singapore, Washington D.C, 2009, p. 272.
[16] K. Krippendorff, Content Analysis: an Introduction to its Methodology, 2.th ed, Sage Publications, Inc, Thousand Oaks, London, New Delhi, 2004, p. 413.
[17] M. Steinert, A dissensus based online Delphi approach: an explorative research tool, Technol. Forecast. Soc. Change. 76 (3) (2009) 291–300.
[18] J.P. Martino, A review of selected recent advances in technological forecasting, Technol. Forecast. Soc. Change. 70 (8) (2003) 719–733.
[19] R. Endacott, C.M. Clifford, J.H. Tripp, Can the needs of the critically ill child be identified using scenarios? Experiences of a modified Delphi study, J. Adv. Nurs. 30 (3) (1999) 665–676.
[20] S. Pätäri, Industry- and company-level factors influencing the development of the forest energy business — insights from a Delphi Study, Technol. Forecast. Soc. Change. 77 (1) (2010) 94–109.
[21] A. Martelli, Scenario building and scenario planning: state of the art and prospects of evolution, J. Futures Res. Q. 17 (3) (2001) 57–74.
[22] S.M. Millett, The future of scenarios: challenges and opportunities, Strategy Leadersh. 31 (2) (2003) 16–24.

Please cite this article as: M. Nowack, et al., Review of Delphi-based scenario studies: Quality and design considerations, Technol. Forecast. Soc. Change (2011), doi:10.1016/j.techfore.2011.03.006

[23] N. Nakicenovic, J. Alcamo, G. Davis, B. de Vries, J. Fenhann, S. Gaffin, et al., Special report on emissions scenarios: a special report of Working Group III of the Intergovernmental Panel on Climate Change, in: United Nations Environment Programme, World Meteorological Organization (Eds.), Cambridge University Press, New York, 2000.
[24] P. Bishop, A. Hines, T. Collins, The current state of scenario development: An overview of techniques, Foresight 9 (1) (2007) 5–25.
[25] P.J.H. Schoemaker, Scenario planning: a tool for strategic thinking, Sloan Manage. Rev. 36 (2) (1995) 25–40.
[26] S.P. Schnaars, How to develop and use scenarios, Long Range Plann. 20 (1) (1987) 105–114.
[27] P. Goodwin, G. Wright, Enhancing strategy evaluation in scenario planning: a role for decision analysis, J. Manage. Stud. 38 (1) (2001) 1–16.
[28] P.J.H. Schoemaker, When and how to use scenario planning: a heuristic approach with illustration, J. Forecast. 10 (6) (1991) 549.
[29] R.M. Hassan, R. Scholes, N. Ash, Ecosystems and human well-being: current state and trends: findings of the Condition and Trends Working Group of the Millennium Ecosystem Assessment, Island Press, Washington, 2005, p. 901.
[30] A. Marcus, Strategic foresight: A new look at scenarios, Palgrave Macmillan, Basingstoke, 2009, p. 209.
[31] R.M. Hogarth, S. Makridakis, Forecasting and planning: an evaluation, Manage. Sci. 27 (2) (1981) 115–138.
[32] A. Tversky, D. Kahneman, Judgment under uncertainty: Heuristics and Biases, Sci. 185 (1974) 1124–1131.
[33] P.W.F. van Notten, A.M. Sleegers, M.B.A. van Asselt, The future shocks: on discontinuity and scenario development, Technol. Forecast. Soc. Change. 72 (2) (2005) 175–194.
[34] R. Phelps, C. Chan, S.C. Kapsalis, Does scenario planning affect performance? Two exploratory studies, J. Bus. Res. 51 (3) (2001) 223–232.
[35] R.E. Linneman, J.D. Kennell, Shirt-sleeve approach to long-range plans, Harv. Bus. Rev. 55 (2) (1977) 141–150.
[36] T.J. Chermack, S.A. Lynham, W.E.A. Ruona, A Review of scenario planning literature, Futures Res. Quarterly. (Summer 2001) 7–31.
[37] H.A. Linstone, M. Turoff, The Delphi Method: Techniques and Applications, Addison-Wesley Publ., Reading/Mass, 1975, p. 621.
[38] H. Leibenstein, Bandwagon, snob, and Veblen effects in the theory of consumers demand, Q. J. Econ. 64 (2) (1950) 183–207.
[39] K.Q. Hill, J. Fowles, The methodological worth of the Delphi forecasting technique, Technol. Forecast. Soc. Change. 7 (2) (1975) 179–192.
[40] M. Turoff, The Policy Delphi, in: H.A. Linstone, M. Turoff (Eds.), The Delphi Method: Techniques and Applications, Addison-Wesley Publ., Reading/Mass, 1975.
[41] H.A. Linstone, Eight basic pitfalls: a checklist in the Delphi method, in: H.A. Linstone, M. Turoff (Eds.), The Delphi Method: Techniques and Applications, Addison-Wesley Publ., Reading/Mass, 1975.
[42] P. Tapio, Disaggregative policy Delphi: using cluster analysis as a tool for systematic scenario formation, Technol. Forecast. Soc. Change. 70 (1) (2002) 83–101.
[43] M. Turoff, The design of a policy Delphi, Technol. Forecast. Soc. Change. 2 (2) (1970) 149–171.
[44] O. Kuusi, M. Meyer, Technological generalizations and leitbilder—the anticipation of technological opportunities, Technol. Forecast. Soc. Change. 69 (6) (2002) 625–639.
[45] P. Rikkonen, P. Tapio, Future prospects of alternative agro-based bioenergy use in Finland—constructing scenarios with quantitative and qualitative Delphi data, Technol. Forecast. Soc. Change. 76 (7) (2009) 978–990.
[46] T. Gordon, A. Pease, RT Delphi: an efficient, "round-less" almost real time Delphi method, Technol. Forecast. Soc. Change. 73 (4) (2006) 321–333.
[47] M. Häder, S. Häder, Die Delphi-Technik in den Sozialwissenschaften-Methodische Forschung und innovative Anwendungen, Westdeutscher Verlag, Wiesbaden, 2000, p. 236.
[48] C. Okoli, S.D. Pawlowski, The Delphi method as a research tool: an example, design considerations and applications, Inform. Manage. 42 (1) (2004) 15–29.
[49] R. Schmidt, K. Lyytinen, M. Keil, P. Cule, Identifying software project risks: an international Delphi study, J. Manage. Inf. Syst. 17 (4) (2001) 5–36.
[50] P.J.H. Schoemaker, When and how to use scenario planning: a heuristic approach with illustration, J. Forecast. 10 (6) (1991) 549–564.
[51] P.J.H. Schoemaker, Multiple scenario development: its conceptual and behavioral foundation, Strateg. Manage. J. 14 (3) (1993) 193–213.
[52] T.J. Chermack, Assessing the quality of scenarios in scenario planning, Futures Res. Q. 22 (4) (2006) 23–35.
[53] C.C. Stewart, Integral scenarios: reframing theory, building from practice, Futures 40 (2) (2008) 160–172.
[54] J. Alcamo, Environmental futures: the practise of environmental scenario analysis, in: A.J. Jakeman (Ed.), Developments in Integrated Environmental Assessment-Volume 2, 1.th ed, Elsevier, Amsterdam, 2008.
[55] P.J.H. Schoemaker, When and how to use scenario planning: a heuristic approach with illustration, J. Forecast. 10 (6) (1991) 549–564.
[56] M.B. Miles, A.M. Huberman, Qualitative Data Analysis: an Expanded Sourcebook, 2.th ed, SAGE publications, Inc, Thousands Oaks, London, New Delhi, 1994, p. 338.
[57] R.W. Woodman, J.E. Sawyer, R.W. Griffin, Toward a theory of organizational creativity, Acad. Manag. R. 18 (2) (1993) 293–321.
[58] F. Abadie, M. Friedewald, K.M. Weber, Adaptive foresight in the creative content industries: anticipating value chain transformations and need for policy action, Sci. Public Pol. 37 (1) (2010) 19–30.
[59] G. Hupkes, Delphi opinion poll Fuchan I, Transportation 3 (1) (1974) 59–81.
[60] A. Pal, S. Maji, O.P. Sharma, M.K.G. Babu, Vehicular emissions: estimation, future prediction and control strategies for the capital city of India, Int. J. Appl. Eng. Res. 4 (7) (2009) 1391–1411.
[61] Y. Al-Saleh, Renewable energy scenarios for major oil-producing nations: the case of Saudi Arabia, Futures 41 (9) (2009) 650–662.
[62] A. Ariel, Delphi forecast of the dry bulk shipping industry in the year 2000, Marit. Policy Manage. 16 (4) (1989) 305–336.
[63] R. Bijl, Delphi in a future scenario study on mental health and mental health care, Futures 24 (3) (1992) 232–250.
[64] K. Czaplicka-Kolarz, K. Stańczyk, K. Kapusta, Technology foresight for a vision of energy sector development in Poland till 2030. Delphi survey as an element of technology foresighting, Technol. Forecast. Soc. Change. 76 (3) (2009) 327–338.
[65] T.G. Eschenbach, G.A. Geistauts, A Delphi forecast for Alaska, Interfaces 15 (6) (1985) 100–109.
[66] J.E. Fleming, The future of U.S. government–corporate relations, Long Range Plann. 12 (4) (1979) 20–26.
[67] J.A. Gómez-Limón, A. Gómez-Ramos, G. Sanchez Fernandez, Foresight analysis of agricultural sector at regional level, Futures 41 (5) (2009) 313–324.
[68] T.J. Gordon, Energy forecasts using a "Roundless" approach to running a Delphi study, Foresight 9 (2) (2007) 27–35.
[69] M. Höjer, Transport telematics in urban systems—a backcasting Delphi study, Transport. Res. 3 (6) (1998) 445–463.
[70] F. Kropp, Changing values: a 2020 vision, J. Euromarket. 12 (3) (2003) 79–97.
[71] T.J.B.M. Postma, J.C. Alers, S. Terpstra, A. Zuurbier, Medical technology decisions in The Netherlands: how to solve the dilemma of technology foresight versus market research? Technol. Forecast. Soc. Change. 74 (9) (2007) 1823–1833.
[72] Y. Shiftan, S. Kaplan, S. Hakkert, Scenario building as a tool for planning a sustainable transportation system, Transport. Res. 8 (5) (2003) 323–342.
[73] O. Sviden, Scenarios: on expert generated scenarios for long range infrastructure planning of transportation and energy systems, Technol. Forecast. Soc. Change. 33 (2) (1988) 159–178.
[74] F. Tseng, A. Cheng, Y. Peng, Assessing market penetration combining scenario analysis, Delphi, and the technological substitution model: the case of the OLED TV market, Technol. Forecast. Soc. Change. 76 (7) (2009) 897–909.
[75] M. Volman, A variety of roles for a new type of teacher educational technology and the teaching profession, Teach. Teach. Educ. 21 (1) (2005) 15–31.
[76] H.A. von der Gracht, I. Darkow, Scenarios for the logistics services industry: a Delphi-based analysis for 2025, Int. J. Prod. Econ. 127 (1) (2010) 46–59.
[77] M. Waissbluth, A. de Gortari, A methodology for science and technology planning based upon economic scenarios and Delphi techniques – the case of Mexican agroindustry, Technol. Forecast. Soc. Change. 37 (4) (1990) 383–397.
[78] M. Wilenius, J. Tirkkonen, Climate in the making, Futures 29 (9) (1997) 845–862.
[79] P.L.F. Zuber, J.M. Mann, F. Paccaud, M.R. Reich, M. Turoff, Introducing a first AIDS vaccine in Switzerland: a policy Delphi analysis, Soc. Prev. Med. 41 (2) (1996) 126–127.
[80] O. Svidén, Future information systems for road transport: a Delphi panel-derived scenario, Technol. Forecast. Soc. Change. 33 (2) (1988) 159–178.
[81] R. Phaal, C.J.P. Farrukh, D.R. Probert, Technology roadmapping: a planning framework for evolution and revolution, Technol. Forecast. Soc. Change. 71 (1–2) (2004) 5–26.
[82] J.A. Gómez-Limón, A. Gómez-Ramos, G. Sanchez Fernandez, Foresight analysis of agricultural sector at regional level, Futures 41 (5) (2009) 313–324.
[83] D. Leonard, S. Sensiper, The role of tacit knowledge in group innovation, in: D.E. Smith (Ed.), Knowledge, Groupware and the Internet, Butterworth-Heinemann, Boston, 2000.

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[84] M.E. Porter, Competitive advantage, Free Press, New York, 1985, p. 557.
[85] M.E. Porter, The five competitive forces that shape strategy, Harv. Bus. Rev. 86 (1) (2008) 78–93.
[86] M. Van Asselt, C. Storms, N. Rijkens-Klomp, J. Rotmans, Towards visions for a sustainable Europe: an overview and assessment of the last decade of European scenario studies, ICIS Masstricht University, Maastricht, 1998, p. 96.
[87] H. Tibbs, Sustainability, Deeper News J. Glob. Bus. Netw. 10 (1) (1999) 1–76.
[88] R.E. Freeman, Strategic management: a stakeholder approach, 2010th ed, Cambridge University Press, Cambridge, 2010, p. 292.
[89] Y. Fassin, The stakeholder model refined, J. Bus. Ethics 84 (1) (2009) 113–135.

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7 Journal Article E3: Scenarios for the sanitation sector: a Delphi-based approach

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Scenarios for the sanitation sector in Germany: a Delphi-based approach

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Abstract

The capital intensive and path-dependent sanitation sector is vulnerable to changing environmental conditions, as the current experiences with decreasing populations in East Germany are proving. Therefore, alternative planning approaches which allow decision-makers in the sanitation sector to prepare early enough for future challenges are needed. In this article I present the results of a scenario study on the future of the sanitation sector in the year 2050 in which I investigated the possibilities of scenario planning to overcome possible shortcomings of former planning approaches. The major contributions of my research are the identification of the most relevant future challenges and the development of a set of future scenarios which provide a valuable basis for strategy development in the sanitation sector.

1 Introduction[1]

Germany[2] is attested by the Organization for Cooperation and Development (OECD) a very high rate of coverage by advanced sanitation services and especially by tertiary treatment. [*OECD*, 2009][3] The reliability of this infrastructure is of crucial importance for our society, as the OECD [2007] underlines:

> *"The long-term future performance of OECD economies, and of the global economy, will depend to an important extent on the availability of adequate infrastructures to sustain growth and social development."*

This high level is financed in OECD and BRIC[4] countries by current expenditures on water and wastewater services summing up to 405 billion US-Dollars ($bn) each year. Germany spends 17.932 $bn each year, corresponding to 0.75 % of its gross domestic product (GDP). [*OECD*, 2009]

At the global level the water and sanitation sector is confronted by manifold challenges as identified by the World Water Development Report of the United Nations World Water Assessment Programme (UNWWAP) [2009]. Among the most important challenges are population dynamics such as growing or shrinking populations, changing age distributions, urbanization and mitigation, economic challenges such as globalization, food and energy scarcity, as well as social challenges and technological changes.[5] The fourth Global Environmental Outlook of the United Nations Environment Programme (UNEP) [2007] describes the challenges with respect to water as follows:

> *"The quantity and quality of surface- and groundwater resources, and life-supporting ecosystem services are being jeopardized by the impacts of population growth, rural to urban migration, and rising wealth and resource consumption, as well as by climate change."* [*UNEP*, 2007]

In order to adapt to these dynamics, but also to maintain and replace the existing infrastructure, significant investments will be required. In the decade 2020-2030 the yearly expenditures in the OECD and BRIC countries for infrastructure networks expenses for the water and sanitation sector are expected to be the highest in the world among road, rail, telecoms[6] and electricity. [*OECD*, 2009] In all OECD and BRIC countries it is predicted that the yearly expenses will increase from 405 $bn to 6,212 $bn by 2015 and to 9,003 $bn in 2025. In Germany the expenditures are expected to increase from 17.932 $bn to 23.38 $bn in 2015 and

1 This article was mostly inspired by two scholars. The first in the sense of a conversant is the work of Dominguez et al. [2006; 2009] and the second in the sense of an exemplar are von der Gracht and Darkow [2010]. Huff [1999; 2008] describes a conversant as an article or work in which one's own article starts a conversation. An exemplar is defined as an article that uses a comparable methodology but in a different context and that can assist as a guideline for structuring one owns work.

2 As well as Austria, Denmark, Finland, Netherlands, Sweden and Switzerland.

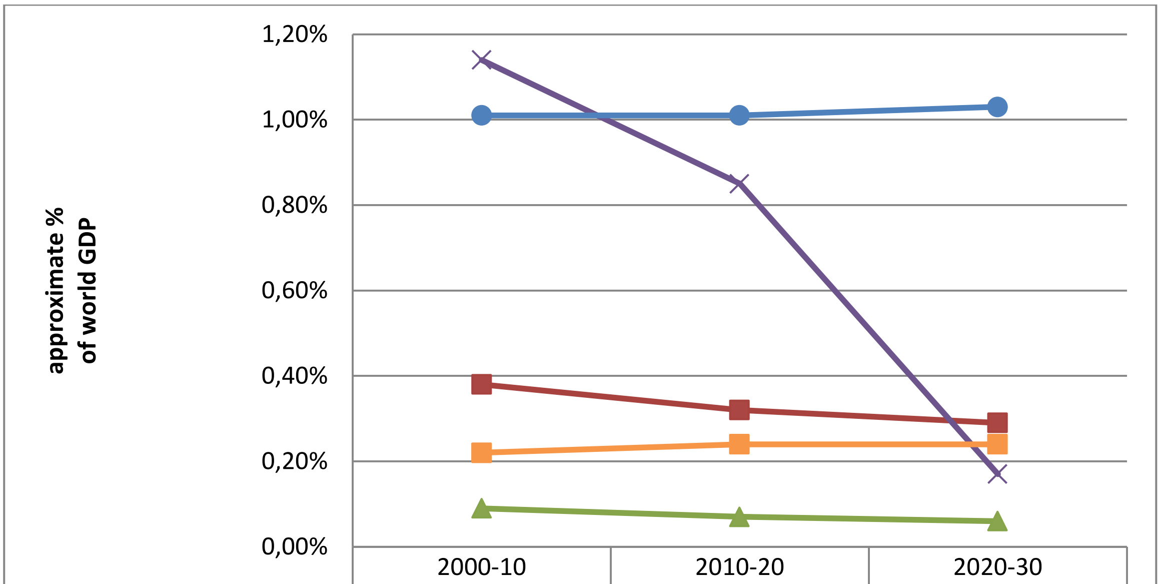
3 Most of the developing countries, especially in Sub-Sahara Africa, are not on track to meet the Millennium Development Goal to halve by 2015, the proportion of people without sustainable access to basic sanitation. Whereas rapid progress can be observed in domestic water supply in almost all regions of the world, sanitation still lags. That's why the UN General Assembly declared 2008 the International Year of Sanitation. [*WHO and UNICEF*, 2008]

4 Brazil, Russia, India and China

5 The OECD [2007] adds to these challenges geopolitics, security and finance. Where especially the latter is more important for the water and sanitation sector, the first two are of higher importance for energy and transport infrastructures.

6 Telecommunications is mainly defined as concerning telephones.

35.84 $bn in 2025, increasing the expenses per GDP share from 0.75 % to 0.83 %. [*OECD*, 2009] See also Figure 1.



	2000-10	2010-20	2020-30
Road	0,38%	0,32%	0,29%
Rail	0,09%	0,07%	0,06%
Telecoms	1,14%	0,85%	0,17%
Electricity	0,22%	0,24%	0,24%
Water and Sanitation	1,01%	1,01%	1,03%

Figure 1: Share of current expenditures of gross domestic product (GDP) in OECD and BRIC countries for road, rail, telecoms, electricity, and water and sanitation infrastructures

The capital intensity of the sanitation sector involves a high degree of fixed costs and low rates of return. [*OECD*, 2009] In combination with the long use-life especially of the sewer system of more than 80 years and in some cases of even more than 100 years [*Baur and Herz*, 2002; *Kaempfer and Berndt*, 1999; *Lemer*, 1996] the sanitation sector is especially vulnerable to path dependency [*Pierson*, 2000] and sunk costs [*Kirkpatrick et al.*, 2006; *Rees*, 1998] as discussed by Hiessel and Toussant [1999], Huitema and Meijerink [2007] as well as by Ingram and Fraser [2006].

In view of the long term impacts that go along with infrastructure investments, strategic planning approaches that can deal with such determining, long range decisions and the involved uncertainty caused by changing environmental conditions seem to be indispensable. But as Dominguez and Guyer [2009] underline, decision-makers in the sanitation sector are not aware of the long-term dynamics of the system and mostly rely on forecasts and the assumption that the future can be predicted based on extrapolations of past trends. This "*capability gap*" [*Dominguez et al.*, 2009] to deal with long range challenges has also been identified by the OECD [2007], which recommends the strengthening of strategic planning capacities by supporting long range planning approaches to infrastructure planning.

In Germany the planning deficit has become obvious in the context of demographic changes. Whereas in most regions of the world demographic change implicates a growth of the population [*UNDESA,* 2007], in Germany the population is shrinking and ageing. [*Federal Statistical Office of Germany,* 2010] In East Germany, demographic change was reinforced by structural and economic changes initiated by the reunification process. Additionally, important parts of the East German sanitation system needed to be modernized to the high standards of the Federal Republic. At the time the newly installed infrastructure was designed for growing populations and "*blooming landscapes*"[7]. But the contrary turned out to be true in most of the East German regions, leading to oversized wastewater systems and, as a consequence, rising wastewater fees due to the high degree of fixed costs. [*Hillenbrand et al.,* 2010; *Hummel and Lux,* 2007; *Nowack et al.,* 2010; *Schlör et al.,* 2009]

Scenario planning is one of the most promising long range planning approaches that support decision-makers to bridge this gap and overcome the difficulties of traditional planning instruments. [*Miller and Waller,* 2003; *Phelps et al.,* 2001; *Schnaars,* 1987; 2001; *Schoemaker,* 1991; 1993; 1995; *Schwartz,* 1998; *Slaughter,* 2002a; *Slaughter,* 2002b]

Scenario planning was originally developed for military purposes by the RAND Corporation in the United States during the Cold War, and later adopted by the civil sector. [*Bradfield et al.,* 2005] At the RAND Corporation, Herman Kahn developed scenarios dealing with possible causes for nuclear war between the US and the Soviet Union in the 1950s for the Air Defense System Missile Command. [*Kahn,* 1960; *Kahn and Wiener,* 1967] Herman Kahn is therefore often seen as the father of modern scenario planning. Pierre Wack's application of Kahn's method at Royal Dutch Shell is deemed to be the first well-documented business application of scenario planning [*Wack*, 1985], and is still used today by the company [*Cornelius et al.,* 2005; *Royal Dutch Shell,* 2005; *Shell International,* 2010].

Since then, scenarios have been used by multiple planners, researchers and practitioners and adopted to their specific needs, which has resulted in a "*methodological chaos.*" [*Martelli,* 2001] Several authors place emphasis on systematizing and structuring the current body of methodological scenario literature and applications. [*Bishop et al.,* 2007; *Bradfield et al.,* 2005; *Börjeson et al.,* 2006; *Chermack et al.,* 2001; *Godet,* 2000; *Lempert et al.,* 2009; *Malaska et al.,* 1984; *Mietzner and Reger,* 2005; *Nowack et al.,* 2011; *van Notten et al.,* 2003; *Varum and Melo,* 2010]

In view of the "methodological chaos", it is very important to build upon existing research and to be semantically precise. Therefore I need to clarify some definitions. In this article I consider a scenario as a "*description of a possible future state* [of the analyzed system]" and adopt thereby the definition of the Intergovernmental Panel on Climate Change (IPCC) [2000]. Very often the term scenario is used as a synonym for a set of specific values of different assumptions, especially in more natural scientific oriented studies. Often these studies are much closer to predictions than to strategic planning scenarios in the sense of Kahn and Wack. Scenario planning is consequently the entire decision-making process that develops and analyzes scenarios and derives the necessary consequences for today's decision. [*Bishop et al.,* 2007; *Chermack et al.,* 2001] The scenario approach describes the steps that are necessary to complete an entire scenario planning project. Bishop et al. [2007] describe a generic

[7] Helmut Kohl (former chancellor of the Federal Republic) used the words "blooming landscapes" to describe his vision of the future development of the East German Federal States of Germany after the break down of the wall. [*Federal Government of Germany,* 1990]

scenario planning approach which is essentially congruent with the approach of Voros [2003]. Bishop's approach consists of two phases which are characteristic for a complete scenario planning study: in the first phase a set of possible futures states of the future is developed. In the second phase the scenarios are analyzed and the consequences for today's decisions are drawn. The development phase is cut into three sub-steps: scenario framing, scanning, and forecasting, and another three steps in the transfer phase: visioning, implementing and controlling. In this article I focus on the first three steps.

Beside the study design, another differentiating factor is the scenario goal. Börjeson et al. [2006] differentiate between predictive and explorative scenarios. Predictive scenarios answer the question: What will happen? They focus on specific drivers and their impacts on the analyzed system. Further characteristics are a short time horizon and a more quantitative study design.

> *"Predictive scenarios are primarily drawn up to make it possible to plan and adapt to situations that are expected to occur. They are useful to planners and investors, who need to deal with foreseeable challenges and take advantage of foreseeable opportunities. Predictions can also be used to make decision-makers aware of problems that are likely to arise if some condition on the development is fulfilled. […] Predictions can also be self-fulfilling. Predicted traffic growth may, for instance, lead to the building of more roads, which stimulates an increase in traffic. The self-fulfilling aspect of predictions makes it possible to use them also for long-term planning and investments in infrastructure. However, the fact that predictions can contribute to preserving past and present trends can also make it more difficult to change undesirable trends." [Börjeson et al., 2006]*

Whereas explorative scenarios provide an answer to the question: What can happen? Thus the focus lies on the identification of the drivers or challenges, a long time horizon and a more qualitative oriented study design.

> *"Explorative scenarios can help explore developments that the intended target group in one way or another may have to take into consideration. This can be in situations when the structure to build scenarios around is unknown, e.g. in times of rapid and irregular changes or when the mechanisms that will lead to some kind of threatening future scenario are not fully known. Explorative scenarios can also be useful in cases when the user may have fairly good knowledge regarding how the system works at present, but is interested in exploring the consequences of alternative developments. Explorative scenarios are mainly useful in the case of strategic issues [van der Heijden et al., 2002]." [Börjeson et al., 2006]*

The possibilities of scenario planning have been increasingly adopted for the water and sanitation sector, see also Table 1 and Table 2. In the water research context, scenarios are often used in a predictive way. [*Chenoweth and Wehrmeyer,* 2006; *Mahmoud et al.,* 2011; *Soboll et al.,* 2011; *Straatsma et al.,* 2009] In Europe, the water framework directive and its call for more participation pushes studies that analyze the possibilities of scenario planning as a tool for stakeholder participation. [*Caille et al.,* 2007; *Hatzilacou et al.,* 2007; *Jessel and Jacobs,* 2005; *Kok et al.,* 2011; *Valkering et al.,* 2010]

A prominent use of scenarios is the use in global environmental outlooks. Besides the water related work of the IPCC [2008], water plays an important role, among others, in the Environmental Outlook of the OECD [2008], in the Gobal Environmental Outlook of the United Nations Environmental Programme (UNEP) [2007] as well as in the Millennium Ecosystem Assessment coordinated as well by the UNEP [2005].

Water plays the key role in the Global International Waters Assessment [*UNEP,* 2006] as well as in the scenario study of the World Business Council on Sustainable Development [*WBCSD*, 2006] "Business in the World of Water - Water Scenarios to 2025". Further global scenario studies with a focus on water can be found in the following Table 1.

Table 1: Global Water Scenario Studies

Reference	Title	Description
[*World Water Council*, 2000]	World Water Vision	analysis of the state of the global water resources
[*International Food Policy Research Institute*, 2002]	World water and food to 2025	water as a determining resource for food safety
[*UNEP*, 2006]	Global International Waters Assessment (GIWA)	systematic assessment of the environmental conditions and problems in transboundary waters
[*WBCSD*, 2006]	Business in the World of Water - water Scenarios to 2025	analysis and awareness raising of potential water risks for companies
[*International Water Management Institute*, 2007]	Water for Food, Water for Life	efficient water management in agriculture for a safe food supply

Very few studies have a comparable local focus and the same explorative scenario goal as the study presented in this article. One of the closest studies is the study of Hiessel et al. [2002]. They evaluate three different future urban water systems for Germany in which they integrate different technological, organizational and institutional innovations. They describe three possible states of the infrastructure system, mostly varying the degree of separation of the various water and wastewater streams. But they do not assess which possible drivers or challenges might lead to this outcome. Nevertheless, the three system scenarios describe possible technological developments of the infrastructure system and one of their scenarios will be reflected in my "Recycling-First" scenario. The scholars of the Eidgenössische Technische Hochschule Zürich [*Lienert et al.*, 2006; *Störmer et al.*, 2009] as well as Dominguez et al. [2009] develop explorative scenarios for Switzerland. Nevertheless, so far no explorative scenario study exists for the German sanitation sector, which focuses on the identification of possible future challenges. Even though global and national trends from other scenario studies are partially applicable to Germany, the particularity of the German sanitation sector as described in Kraemer and Hansen [2004] requires the development of customized scenarios.

My two main research questions (RQ) are therefore:

1. What are possible future challenges that the sanitation sector in Germany has to be prepared for in the future?
2. What are possible future states of the sanitation sector in Germany in the year 2050?

Besides the real world research interest, I also develop and test a new Delphi-based scenario methodology which will be described in detail in the next chapters. Moreover, I emphasize the possibilities of the Delphi technique within scenario development to identify weak signals

[*Rossel,* 2009] as an important prerequisite to identify and prepare for discontinuities or shocks [*Saritas and Smith,* 2011; *van Notten et al.,* 2005]

The scenarios are developed primarily for decision-makers at the executive and management levels, but can be used as well on regional and national levels by politicians and governments for developing long range strategies to facilitate the incorporation of possible future challenges. Consequently, I conduct an explorative scenario study. The purpose of this scenario study is therefore to enhance organizational adaptation and learning by recognizing and interpreting external signals of a changing environment. [*Berkhout et al.,* 2006; *Chermack and Van Der Merwe,* 2003; *Galer and van der Heijden,* 2001; *Phelps et al.,* 2001] I support this process by the highest possible degree of integration of sanitation professionals, administrative authorities, as well as academic experts. I do so by applying the Delphi technique and organizing workshops to which I regularly invited relevant stakeholders. The target time horizon is specified with the year 2050, but this is rather a symbolic value. I intended rather not to develop scenarios for exactly the mentioned point in time, but much more to develop scenarios for a time period that allows not only incremental adjustments but also structural changes. [*Kindler,* 1979; *Miller and Friesen,* 1982; *Wright et al.,* 2008]

The remainder of my paper is organized as follows: after having introduced my research and presented the research question, I start explaining how I will answer my research questions by describing the necessary background and the research methodology. Subsequently, I present my findings with respect to the Delphi survey, the Fuzzy Cognitive Map analysis, the business-as-usual scenario and the final explorative scenarios. Finally, I discuss the results and the methodology and conclude giving recommendations on how decision-makers might use the results.

Table 2: Overview of explorative scenario studies in the water and sanitation sector[8]

Study	Title	Purpose	Region	Time frame
[*Straton et al.*, 2010]	Exploring and Evaluating Scenarios for a River Catchment in Northern Australia Using Scenario Development, Multi-criteria Analysis and a Deliberative Process as a Tool for Water Planning	identification of future challenges and stakeholders interests	Australia	20 years
[*O'Connor et al.*, 2005]	The Avon River Basin in 2050: Scenario planning in the Western Australian Wheatbelt	strategic regional planning	Australia	2050
[*Christoph et al.*, 2008]	IMPETUS: Implementing HELP in the upper Ouémé basin	analysis of the impacts of different economic, demographic, and climate developments on water resources	Benin and Morocco	2050
[*Kok et al.*, 2011]	Combining participative backcasting and exploratory scenario development: Experiences from the SCENES project	identification of important trends, development of stakeholder-based scenarios, used as input for hydrological modelling	Europe	2050
[*Jessel and Jacobs*, 2005]	Land use scenario development and stakeholder involvement as tools for watershed management within the Havel River Basin	development of land use scenarios based on stakeholder interviews, used as input for hydrological modelling	Germany	2015
[*Hiessl et al.*, 2002]	Design and sustainability assessment of scenarios of urban water infrastructure systems	analysis of different technological, organizational and institutional innovations in three prepared scenarios	Germany	2050
[*Hatzilacou et al.*, 2007]	Scenario workshops: A useful method for participatory water resources planning?	discussion of prepared scenarios, identification of preferred future, derivation of action needs	Greece	2020
[*Valkering et al.*, 2010]	Scenario analysis of perspective change to support climate adaptation: lessons from a pilot study on Dutch river management	stakeholder participation	Netherlands	"toward the future"
[*De Jong et al.*, 1989]	Scenario planning for water resources: a Saudi Arabian case study	modelling based on business-as-usual and most probable policy scenarios	Saudi Arabia	2000
[*Caille et al.*, 2007]	Participatory scenario development for integrated assessment of nutrient flows in a Catalan river catchment	identification and analysis of external drivers that impinge on nutrient emissions	Spain	2030
[*Lienert et al.*, 2006]	Future Scenarios for a Sustainable Sector: A Case Study from Switzerland	expert-based scenario development for the Swiss (waste)water sector	Switzerland	20-30 years
[*Störmer et al.*, 2009]	The exploratory analysis of trade-offs in strategic planning: Lessons from Regional Infrastructure Foresight	strategic planning in the sanitation sector on management level	Switzerland	25 years
[*Means et al.*, 2005b] and [*Means et al.*, 2005a]	Scenario planning: A tool to manage future water utility uncertainty	strategic planning for water utilities	USA	2025

[8] The overview is result of a literature search using the scopus database. The search resulted in 75 hits from which pure modelling and predictive scenario studies were excluded. The scopus search string was: (TITLE-ABS-KEY(wastewater AND "scenario planning") OR TITLE-ABS-KEY(sanitation AND "scenario planning") OR TITLE-ABS-KEY(sewer AND "scenario planning") OR TITLE-ABS-KEY(wastewater AND "scenario development") OR TITLE-ABS-KEY(sanitation AND "scenario development") OR TITLE-ABS-KEY(sewer AND "scenario development") OR TITLE-ABS-KEY(wwtp AND "scenario development") OR TITLE-ABS-KEY(wwtp AND "scenario planning") OR TITLE-ABS-KEY(water AND "scenario development") OR TITLE-ABS-KEY(water AND "scenario planning")).

2 Method

I decided to gather the necessary input for the scenarios by integrating the expertise of sanitation professionals, researchers and specialists from the authorities by relying on the Delphi technique. The Business-as-Usual scenario is constructed based on the top 15 challenges identified during the Delphi procedure. The driver interdependency of the top 15 challenges are analyzed by developing a Fuzzy Cognitive Map (FCM) and summarized in a Business-as-Usual scenario. The Business-as-Usual scenario is completed by three explorative scenarios derived from visionary expert statements. The research process is illustrated in the following Figure 2 and explained step by step in the following chapters, after having introduced to the Delphi technique.

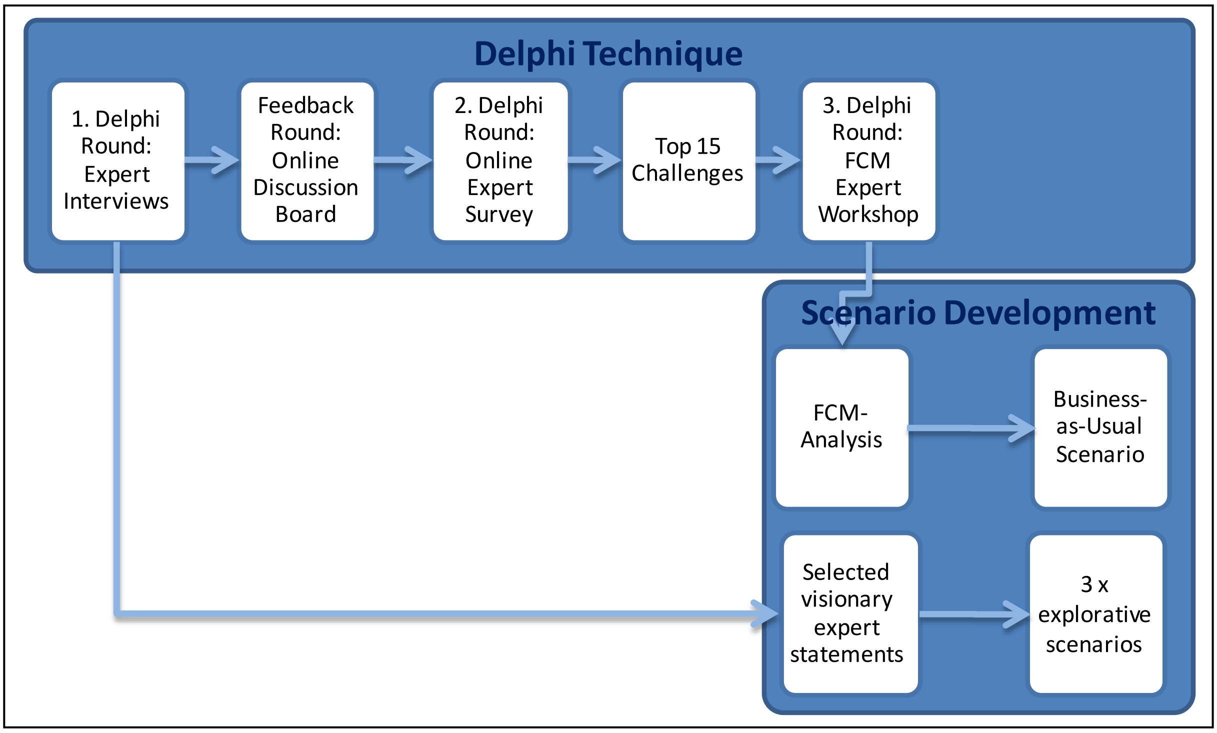


Figure 2: Research Design

2.1 Delphi technique

The Delphi technique itself is defined as

> *"a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem."* [*Linstone and Turoff*, 1975]

As I described in my article [*Nowack et al.*, 2011] on Delphi-based scenario studies:

> *"The key design elements of the Delphi technique are anonymity, iteration, controlled feedback and participating experts [Landeta, 2006; Linstone and Turoff, 1975; Rowe and Wright, 1999]. In most Delphi studies (as identified in [Gupta and Clarke, 1996] and [Landeta, 2006]), a number of experts is each given an anonymous questionnaire to answer questions concerning their field of expertise.*
>
> *The most important argument for anonymity is the possibility to avoid negative impacts of group communication processes similar to the "Bandwagon effect" [Leibenstein, 1950]. In Delphi studies, controlled feedback is provided to the experts in the*

form of quotes, summaries, median or mean statistics. The experts are then asked to comment on the responses of the other experts, defend their own positions, develop new ideas and/or answer new questions introduced by the monitoring team. The results are often presented as a statistical group response.

Iteration is especially important if the main purpose of the Delphi technique is to seek consensus as is the case in the Classical Delphi. The Classical Delphi is similar to the Delphi studies that were prepared by the RAND Cooperation, and it has been subject to severe criticism since the late 70's [Hill and Fowles, 1975; Linstone, 1975; Turoff, 1975]. Due to the criticism, some modifications of the Delphi technique have been suggested [Tapio, 2002]. The Policy Delphi proposed by Turoff [1970] *seeks opposing views on the topic at hand. Kuusi and Meyer* [2002] *further developed the Policy Delphi into the Argument Delphi in which the arguments, collected in the precedent Delphi questionnaire, are further discussed in groups. Tapio* [2002] *as well as Rikkonen and Tapio* [2009] *use a cluster analysis in their Disaggregative Policy Delphi as a basis for the development of the scenarios.*

Further adaptations of the Delphi technique affect the iteration and feedback. In a Real Time Delphi [Steinert, 2009] and [Gordon and Pease, 2006], the use of the Internet and corresponding programming allows immediate feedback after the experts have answered the questionnaire via web-based applications. Other experts are, thus, able to respond, comment, or argue immediately, which allows direct feedback and almost infinite iteration." [*Nowack et al.,* 2011]

If the Delphi technique is integrated in a scenario study, it can support the scenarist mainly by three functions [*Nowack et al.,* 2011]: the idea generation, the consolidation, and the judgment function. The idea generation function makes use of experts to support the scenarist to generate ideas on possible future challenges, which is especially fruitful in the scanning phase of a scenario project. Scenario planners need often to evaluate the identified drivers and to consolidate them in the forecasting step of a scenario study. Experts can do this by evaluating or ranking the identified drivers by relying on the consolidation function of the Delphi technique. The judgment function is often used in the visioning phase of a scenario study. Experts can evaluate in this step which consequences need to be drawn from the developed scenarios. [*Nowack et al.,* 2011] I have decided to integrate the Delphi technique in the scanning as well as in the forecasting step of my scenario study by relying on the idea generating and consolidation functions.

2.1.1 First Delphi Round: Expert Interviews

I started the Delphi process by conducting 21 expert interviews. The main purpose was to identify possible future challenges and rely on the experts to generate ideas on how the future may unfold. I selected the experts based on several criteria. I invited the authors of pertinent publications, cooperating industry partners (mostly operators of wastewater utilities), important stakeholders as representatives of the administrative bodies of the Free State of Saxony, as well as of the Federal Government.[9] Nearly half of the interviews were conducted face-to-face, whereas the other half was conducted as telephone interviews. During the semi-structured interviews I used an interview guideline that was developed based upon the PESTE framework and the stakeholder model [*Fassin,* 2009; *Freeman,* 2010] in combination with

[9] I also invited representatives of non-governmental organizations to participate, but I had to exclude the interviews from the further analysis because the interviewees could not qualify as experts and the answers did not add any new aspects.

Porter's Five Forces [*Porter,* 1985; 2008]. I asked the experts in open-ended questions to designate possible future political, economic, societal, technological and ecological challenges that might affect the sanitation sector in the year 2050 in Germany. The experts were also asked to nominate possible demands on and of the employees, the owner, the public or the creditors that might play a role in the future and to assess how the five forces that shape competition (suppliers, clients, substitutes, new market entrants, and the competition within the sector) might evolve in the future. I also reminded the experts to think about possible weak signals. The interviews took in average ca. 50 minutes; some of them even took more than one and a half hours. The 21 interviews resulted in 17 hours and 28 minutes of recorded interviews. These records were transcribed into 254 pages of text, or 112,706 words. During the interview and transcription phases I was supported by a team of seminar students. After a training period they conducted a few interviews on their own and were responsible for the entire transcription. The transcription was then used for a summarizing content analysis supported by the content-analysis software MAXQDA. Applicable text passages were marked and assigned to the categories of the interview guideline. The following quote illustrated how I dealt with the inputs from the interviews:

> *"We have the unsolved problem of prions. These proteins cause the mad cow disease, and scrapie as well as the Creutzfeldt-Jakob disease. They are accumulating in the sewage sludge. This is not problematic if the sludge is burned, but it is problematic if the sludge is used for agricultural purposes. […] This is a highly problematic topic and you should discuss if you want to include it in your study because it might start a heated debate"*

I integrated this statement as "accumulation of new so far unknown substances" (POL1) as one possible challenge in my scenario study. In the following runs, redundancies were removed and some of the categories were combined. I found that the stakeholder categories were mostly covered by the PESTE categories and therefore this set of categories was removed. In the end I identified 46 possible future challenges that I assigned to 10 major categories. See also Table 4.

2.1.2 Feedback Round: Online Discussion

The results of the first Delphi round were fed into an online discussion board[10]. Two external experts were asked to review the board and to comment on the results in order to start the conversation. Each participating expert was assigned an anonymous access to the board (www.demowas.de/smf) and was invited to review and comment on the results. The anonymity of the answers as well as of the experts was maintained during the whole Delphi procedure. A short online video explained the basic functions of the discussion board to facilitate the use. The experts were also asked to co-nominate [*Loveridge*, 1999; *Nedeva et al.,* 1996] further experts. I also invited a few experts that I met in workshops after I conducted the interviews. In total, 11 of the 28 experts that had access to the anonymous discussion board visited the board. In general, no new challenges were added, but the probability of occurrence of some items was discussed.

[10] I used the Simple Machines Forum software.

2.1.3 Second Delphi round: Online Expert Survey

The reviewed results of the first Delphi round were then fed into an online survey. In this step, I used the consolidation function of Delphi technique in order to identify the most relevant future challenges. I invited all experts that had participated so far, as well as some additional sanitation professionals. I asked the experts to answer ten questions with 46 items. The experts were asked to evaluate the relevance of the future challenges for the sanitation sector in Germany in the year 2050. I used a Likert-type scale from 1 (very low relevance) to 5 (very high relevance). For a high response rate I decided to keep the questionnaire as simple as possible.[11] In the end the survey took ca. ten minutes time to be completed. 27 from 39 invited experts responded to the questionnaire. The feedback to this second Delphi, the statistical group response, and the top ranked challenges (based on the median relevance of the expert responses) were presented at the beginning of the expert workshop in the next Delphi round.

2.1.4 Third Delphi Round: FCM Expert Workshop

Based on the top 15 future challenges, identified in the second Delphi round, a Fuzzy Cognitive Map was developed and consequently analyzed based on graph theory [*Kosko,* 1986; *Papageorgiou et al.,* 2003], specifically social network analysis [*Grienitz et al.,* 2010; *Özesmi and Özesmi,* 2004]. Fuzzy Cognitive Maps (FCM) were used for the first time in context with scenario planning by Jetter and Schweinfort [2011], Kok [2011] and van Vliet [2010]. Fuzzy Cognitive Maps are essentially causal cognitive maps that are capable of capturing the mental models of experts by simply drawing loop and weighted arrows as illustrated in Figure 3 in the following Box. [*Jetter and Schweinfort,* 2011] Therefore, FCM are especially suited for participatory scenario studies in which implicit expert knowledge needs to be revealed and their adoption in the context of Delphi-based scenario studies appears therefore especially promising. For the third Delphi-round I invited the experts to a workshop. In total 19 experts attended the workshop, among them were eight operators, one representative of the federal state ministry on environment, and three external scientists and the moderating team. Anonymity was assured until the workshop in order to allow the experts also to mention non-mainstream topics. Only during the workshop the participants were introduced to each other, the statements that were given in the preceding steps are still not attributable to any expert.

After an introduction to the topic and an explanation of the methodology, I asked the participants of the expert workshop to illustrate how the top 15 future challenges are affecting the sustainability of the sanitation sector. I integrated three target variables in the FCM in order to facilitate the discussion: economic sustainability (cost-covering wastewater fees), ecological-technical sustainability (good status of the receiving water bodies) and social sustainability (social acceptance and satisfaction with the service). [*European Parliament and European Council,* 2000; *German Advisory Council on Global Change,* 1997] I split the group into two sub-groups to facilitate the communication. In a first step the two groups drew the Fuzzy Cognitive Map without conducting the weighting of the relationships. Then the moderator team compared the two Fuzzy Cognitive Maps and observed a very high degree of concordance. Very few arrows varied, which was a result of different interpretations of some terms.

[11] I announced a lottery of three bottles of organic wine for the first twenty participants that filled in the survey completely.

The moderator team combined the two maps into one map. Finally, in a last step the entire workshop group evaluated the strengths of the relationships.

2.2 Scenario building

The results of the second Delphi round, the online survey, are summarized in a Business-as-Usual scenario. The challenges identified in the first Delphi round and evaluated in the second round are analyzed using Fuzzy Cognitive Maps. This work builds upon the precedent of the methodological work of Jetter and Schweinfort [2011], Kok [2009], and van Vliet [2010]. I use Fuzzy Cognitive Maps primarily to illustrate the complexity and the dynamics of the sanitation system. Often the Cross-Impact Analysis is chosen for the same purpose. [*Bañuls and Turoff,* 201X; *Gordon and Pease,* 2006; *Phelps et al.,* 2001; *Tversky and Kahneman,* 1974] But the high degree of complexity makes this technique less attractive for a participatory scenario study and handicaps starting a learning process. As illustrated in the precedent combinations of Fuzzy Cognitive Maps and scenarios, Fuzzy Cognitive Maps are especially well suited for a participatory approach. The Fuzzy Cognitive Maps developed in the expert workshop are basis for further analysis based on the graph theory [*Kosko,* 1986; *Papageorgiou et al.,* 2003]. In my analysis I used the software FCMappers, which implements the methodology proposed in Özesmi and Özesmi [2004]. To make the inherent steps traceable, I shortly summarize the most important measures and explain the methodology in the following box.

Background of Fuzzy Cognitive Maps and graph theory

Fuzzy Cognitive Maps are essentially causal cognitive maps that are capable of capturing the mental models of experts by simply drawing loop and weighted arrows as illustrated in Figure 3 [*Jetter and Schweinfort*, 2011]. The Fuzzy Cognitive Map can be transformed to a square adjacency matrix $A(D) = [a_{ij}]$ as illustrated in Table 3.

Figure 3: A simple Fuzzy Cognitive Map

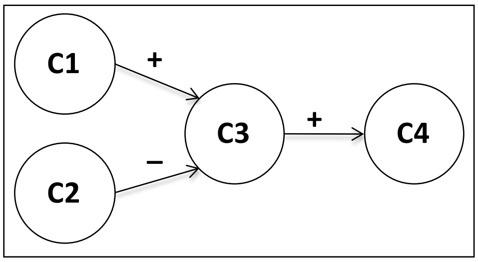


Table 3: Square adjacency matrix

	C1	C2	C3	C4
C1	0	0	1	0
C2	0	0	-1	0
C3	0	0	0	1
C4	0	0	0	0

In the adjacency matrix all the variables are listed on the vertical v_i as well on the horizontal axis v_j. Connections are coded between -1 and +1. In the example in Figure 3, the connection from C1 to C2 would be coded with +1 and the connection from C2 to C3 with -1. In my scenario study I used the coding steps + = 0.25, ++ = 0.5 and +++ = 0.75 and vice versa for negative relationships.
Following graph theory, the adjacency matrix can be analyzed based on the number of variables (N) and the number of connections (C). To compare different Fuzzy Cognitive Maps, the density can be calculated which illustrates the degree of interconnectivity[12]. The formula for the density divides the number of connections by the total number of possible connections.

$$D = \frac{C}{N(N-1)}$$

An analysis of the variables shows which function they fulfill in the illustrated system. There are three types of variables: transmitter, receiver, and ordinary variables. The distinguishing features are the indegree and the outdegree. The outdegree (od) is defined as the sum of the absolute values of a row of a variable. The outdegree stands for the active influencing impact of a variable.

$$od(v_i) = \sum_{k=1}^{N} \bar{a}_{ik}$$

Whereas the indegree (id) is a measure on how much it is driven by other variables. To calculate the indegree I sum up the absolute values of the column values of a variable.

$$id(v_i) = \sum_{k=1}^{N} \bar{a}_{ki}$$

Transmitter variables have a positive outdegree and zero indegree. Receiver variables are characterized by a zero outdegree and a positive indegree. Ordinary variables have a positive in- and outdegree. [*Özesmi and Özesmi*, 2004]

The overall influence of a variable in a matrix can be measured by calculating its centrality. The centrality (c_i) is the sum of the outdegree and indegree of a variable.

$$c_i = od(v_i) + id(v_i)$$

This can be an important indication for a key driver of the analyzed system. [*Grienitz and Schmidt*, 2010]

[12] The total number of possible connections is N², if self-reinforcing effects are allowed.

Finally the system can be simulated, therefore the following steps are necessary:

As described in Özesmi and Özesmi [2004], an initial state vector is multiplied by the adjacency matrix $I^n \times A$. My example from above results in the following new state S vector after the first iteration. This auto-associative neural network method is used to calculate the steady state and repeated until the new state vector is stable. [*Reimann,* 1998]

$$S = I^n \times A = [1 \quad 1 \quad 1 \quad 1] \times \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix} =$$

$$= 1 \times (0,0,1,0) + 1 \times (0,0,-1,0) + 1 \times (0,0,0,1) + 1 \times (0,0,0,0) = (0,0,0,1)$$

Özesmi and Özesmi [2004] apply a monotonic increasing function to the matrix multiplication at each simulation step.[13] They use a logistic, linear threshold or step function $1/(1 + e^{-1 \times x})$ to convert the results between 0 and 1. The main purpose of applying this threshold function is to be able to compare the final activation levels of the variables. In my example, after one iteration I get:

$$(0,0,0,1) \times 1/(1 + e^{-1 \times x}) = [0,5 \quad 0,5 \quad 0,5 \quad 0,731]_1$$

and after 2 iterations the system reaches its stable state at:

$$S_2 = [0,5 \quad 0,5 \quad 0,5 \quad 0,622]$$

These steps are repeated until the system shows a final state.[14] Özesmi and Özesmi [2004] underline that usually the system converges to a stable state after 30 iterations; however, theoretically the system could also settle into a limit cycle, or chaotic attractor.

In the following, additional policy simulations can be run and compared with the steady state outcome. To simulate a policy option, the corresponding value is activated C4=1 and clamped to this, whereas the others are deactivated C1=C2=C3=0. Leading to a new stable state after 2 iterations:

$$S_2^P = [0,5 \quad 0,5 \quad 0,5 \quad 1]_2$$

Finally, the outcome of the steady state with the simulations can be compared by analyzing the relative differences between the values of the steady state and the values of the policy option.[15]

$$S_2^P - S_2 = [0 \quad 0 \quad 0 \quad 0.378]_2$$

In this example the simulation has increased C4 in comparison to the steady state.

I completed the Business-as-Usual scenario based on the Fuzzy Cognitive Map with three explorative scenarios that are not based on the average group response but on the most visionary ideas of some of the experts. The three explorative scenarios highlight different aspects of a possible future sanitation sector. Whereas the “Watershed-First” scenario focuses on an alternative regulatory regime, the “Recycling-First” scenario illustrates a different technological development, as does the “Mega-City” scenario. These scenarios are based on selected expert statements identified in the expert interviews. I have decided to complete the Business-as-Usual scenario with these visionary scenarios in order to overcome traditional mind models and to stimulate creative thinking about alternative futures.

13 Jetter [2011] uses a “binary threshold function that converts inputs of ≤ of 0 to 0 and inputs of > 0 to 1”

14 Kok [2009] discusses possible final states.

15 Whereas Özesmi and Özesmi [2004] as well as Jetter and Schweinfort [2011] compare variations in the initial states vector, Kok [2009] varies specific relationships in the adjacency matrix.

3 Results

3.1 First and Second Delphi Round

In this chapter I will provide an answer for RQ1. Table 4 summarizes the results of the first and second Delphi round. The future challenges together with the corresponding categories represent the summarized results of the first Delphi round. Each variable (Var) is assigned to a category and superordinated PESTE category. The mean and the standard deviation (SD) in Table 4 are the results of the second Delphi round. The top 15 challenges with the highest relevance are marked by an asterisk and also illustrated in Figure 7 in the appendix. In average the experts evaluated “sewer remediation needs” (1.) as the most relevant challenge, followed by “drug residues” (2.) and “short public budgets” (3.).
Furthermore, the results show that among the top 15 challenges the consensus in terms of a relatively low standard deviation is high. The standard deviation among the top 15 challenges varies between 0.64 and 1.01, whereas it varies between 0.82 and 1.23 among the remaining variables. The consensus is especially high for “4th treatment stage” (15.) and the first ranked “sewer remediation needs”. A very high degree of consensus between the experts exists also about the relevance of “drug residues” (2.), “phosphorus recycling” (9.) the “precautionary principle” (6.) and “heavy rainfalls” (4.). The opinion of the experts varies the most concerning the importance of “nanoparticles” (30.) and “reduction of subsidies” (17.).

Table 4: Results of the first and second Delphi round

Category		Var	Name	Description	Mean	SD
Political	New Standards	STA1	Precautionary principle	Avoidance of new pollutants at the source. i.e. approval of medicine only if the medicine is degradable in water	**4.04***	0.73
		STA2	Watershed-regulation	Enlargement of the area of responsibility to watershed level	3.17	1.05
		STA3	Regulation of agriculture	Regulation of agricultural pollutions. i.e. excessive discharge of nutrients	**3.88***	0.88
		STA4	Receiving water-dependent standards	Purification standards vary depending on the status of the receiving waters	3.50	0.98
		STA5	Classical standards	Increase of classical purification standards	**3.84***	0.85
Economic	Sector-specific Development	SEC1	Public relations	Enhancing of the public relation in an open and activating way	3.20	1.15
		SEC2	Formal privatization	Continuation of the trend towards formal organizational privatization. i.e. private partners are called in up to a co-ownership of 49 per cent	2.96	0.82
		SEC3	Cooperation intensity	Inner-city. inter-communal and inter-sectoral cooperation of the wastewater utility	3.56	0.96
		SEC4	Indirect competition	Competition takes only place between specific subservices e.g. sewer cleaning	3.25	1.15
		SEC5	Direct competition	Central sanitation services are in direct competition with decentral solutions. starting at large properties	3.30	0.97
	Finance	FIN1	Allowing of provisions	Legal allowing of provisions (saving funds) for future investment needs e.g. remediation of the sewer system	3.33	1.09
		FIN2	Coordinated charging	Charging in cooperation with water utilities for an optimal water demand management	3.13	0.97
		FIN2	Fix cost-depending charging	Charging of a basic rate in the amount of the fix costs	3.52	1.12
		FIN4	Pollution-depending charging	Charging of wastewater rates that are depending on the degree of the pollution and installation of a corresponding measuring system	3.22	1.09
		FIN5	Short public budgets	Short financial resources of public budgets limit the local government's room for maneuver	**4.12***	1.01
		FIN6	Reduction of subsidies	Considerable reduction of subsidies as important source of investments	3.71	1.23
		FIN7	Revision of rates	Revision of wastewater rates by an independent third party	3.00	0.98
		FIN8	Sustainability checks	Introduction of sustainability or demography checks for investments e.g. as part of appropriations	3.33	0.82
Social	Demo-graphy	DEM1	Population decrease	Decrease of the population due to demographic and structural changes	**4.04***	0.89
		DEM2	Rise in average age	Rise in the average age of the population due to declining birth rates and rising life expectancy	3.28	1.10
		DEM3	Skills shortage	Due to demographic change qualified employees are increasingly difficult to find	3.20	1.04
	Water Demand	WAD1	Decreasing water de-mand (dom.)	Decreasing domestic water demand	**3.85***	0.92
		WAD2	Decreasing water de-mand (ind.)	Decreasing industrial water demand	**3.85***	0.92
Technological	Sewer System	TCS1	Storage capacities	Real time controlling and management of the storage capacities of the sewer system for a better management of heavy rainfalls	3.63	0.92
		TCS2	Trenchless restructuring	Use of trenchless restructing methods for the remediation of the sewer system	3.40	0.91
		TCS3	Stormwater infiltration	Decentral collection. storage and infiltration of stormwater	**4.00***	0.85
		TCS4	Sewer remediation needs	Remediation needs of sewer system	**4.46***	0.71
		TCS5	Separate sewers	Continuation of the separation of the drain and sewer system	**4.08***	0.93
		TCS6	Infrastructure tunnels	Installation of combined infrastructure tunnels (walkable) for better maintenance possibilities. possibility to pull in additional infrastructure pipes (e.g. telecommunication) by winches	2.63	0.92
	Wastewater treatment plant	TCW1	4th treatment stage	Fourth advanced treatment stage to remove new pollutants. e.g. membrane technology	**3.83***	0.64
		TCW2	Disinfection	Disinfection of wastewater before it leaves the wwtp	3.23	0.92
		TCW3	Renewable energies	Use of renewable energy sources at the wwtp. e.g. solar power. fermentation gas etc.	3.80	0.87
		TCW4	Hydropower plants	Installation of wastewater hydropower plants on the wwtp as a standard	3.13	1.03
		TCW5	Sludge hygienisation	Hygienisation of sewage sludge for a better recycling	3.52	0.85
		TCW6	Phosphor recycling	Recycling of phosphor at the wwtp	**3.96***	0.68
		TCW7	Heat recovery	Use of heat from wastewater	3.38	0.85
	Decen-trality	DEC1	Household level reuse	Reuse of water and recycling of nutrients (phosphorus) on household level. cascade use of water	3.08	1.10
		DEC2	Decentral sanitaion	Profuse installation of decentral sanitation systems. in urban as well as in rural areas	3.42	0.99
Environmental	Climate Change	CLI1	Heavy rainfalls	Increased frequency of heavy rainfall	**4.12***	0.82
		CLI2	Heat periods	Increased frequency of drought and heat periods	**3.88***	0.95
		CLI3	Weather phenomena	Increasing vulnerability to unusual weather phenomena	3.27	1.08
	Pollutants	POL1	Unknown substances	Accumulation of new so far unknown substances	3.55	1.06
		POL2	Nanoparticles	Accumulation of nanoparticles in sewage	3.32	1.17
		POL3	Heavy metals	Accumulation of heavy metals in sewage	3.04	0.98
		POL4	Bacteria and viruses	Accumulation of bacteria and viruses in sewage	3.56	1.00
		POL5	Drug residues	Accumulation of drug residues and hormones sewage	**4.12***	0.67

3.2 Third Delphi Round

The top 15 ranked challenges were analyzed by developing a Fuzzy Cognitive Map during the expert workshop. An illustration of the resulting Fuzzy Cognitive Map is given in Figure 4 and Table 5.

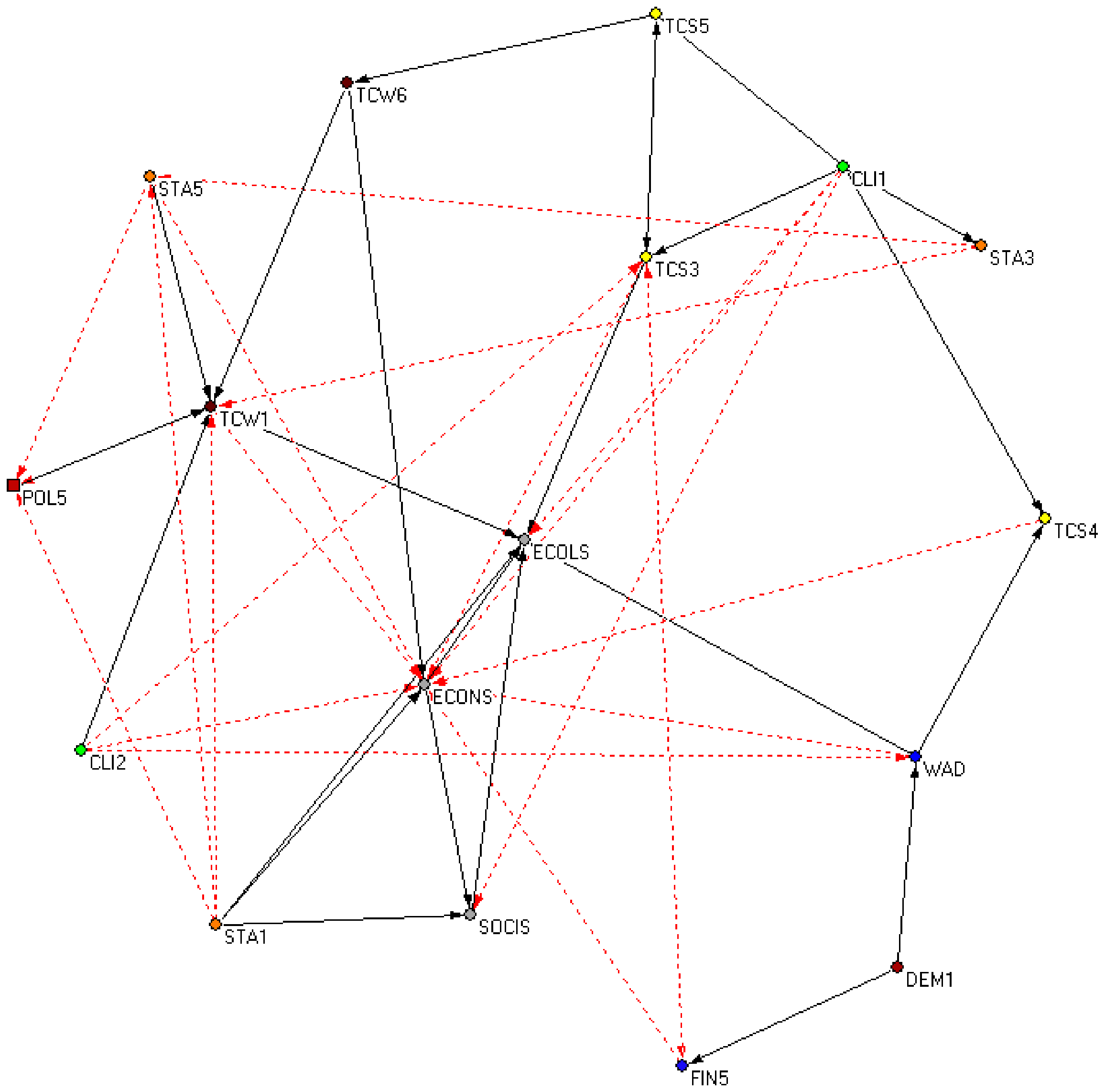


Figure 4: Fuzzy Cognitive Map developed in the expert workshop

The Fuzzy Cognitive Map is characterized by a total of 17 variables[16], 45 connections, 4 transmitters, 1 receiver, and 12 ordinary variables and by a density of 0.1557. The transmitter variables are “heat periods”, “heavy rainfalls”, “population decrease”, and “precautionary principle”, thus they influence other variables but are not affected by others. Except for “population decrease”, these four variables are also characterized by the highest outdegree, i.e. they have the highest impact on other variables.

[16] The two water demand variables WAD1 and WAD2 were integrated in one variable WAD during the FCM workshop.

Table 5: Adjacency Matrix and their graph theoretical indicators

	stormwater infiltration	heat periods	decreasing water demand	seperate sewers	sewer remediation needs	heavy rainfalls	short public budgets	economic sustainability	social sustainability	ecological sustainability	population decrease	precautionary principle	regulation of agriculture	4th treatment stage	drug residues	classical standards	phosphorus recycling	Outdegree
TCS3				0.25			-0.25	-0.25		0.50								1.25
CLI2	-0.25		-0.50					-0.25						0.25				1.25
WAD[17]					0.25			-0.25		0.25								0.75
TCS5	0.75																0.25	1.00
TCS4								-0.75										0.75
CLI1	0.50			0.50	0.25			-0.50	-0.25	-0.50			0.25					2.75
FIN5	-0.25							-0.25										0.50
ECONS									0.75	0.75								1.50
SOCIS										0.25								0.25
ECOLS																		0.00
DEM1			0.25				0.25											0.50
STA1								0.25	0.25	0.25				-0.25	-0.75	-0.25		2.00
STA3														-0.25		-0.25		0.50
TCW1								-0.25		0.50					-0.75			1.50
POL5														0.50				0.50
STA5								-0.25						0.25	-0.75			1.25
TCW6								0.25						0.25				0.50
Indegree	1.75	0.00	0.75	0.75	0.50	0.00	0.50	3.25	1.25	3.00	0.00	0.00	0.25	1.75	2.25	0.50	0.25	
Centrality	3.00	1.25	1.50	1.75	1.25	2.75	1.00	4.75	1.50	3.00	0.50	2.00	0.75	3.25	2.75	1.75	0.75	
Iterations until stability	18	1	2	18	3	1	18	19	19	18	1	1	2	19	19	3	18	

The analysis of Fuzzy Cognitive Map shows that the target variable “ecological sustainability” is only driven by other factors and is not a driver of other variables, and is thus a receiver variable. It also belongs to the variables with the highest indegree, as well as the “economical sustainability, “drug residues” and “4th treatment stage”. “Economic sustainability”, “ecological sustainability, and “drug residues” are also among the variables with the highest centrality.

If the steady state is simulated, the last variables reach a stable state after 19 iterations, whereby the changes of the variable after the third round are only of marginal nature as illustrated in Figure 8 in the appendix. Among the variables that need 19 iterations until they reach a stable state are the target variables “economic and social sustainability” as well as “4th treatment stage”, and “drug residues”. “Storm water infiltration”, separate sewers”, “ecological sustainability”, sShort public budgets” and “phosphorus recycling” stabilize after 18 iterations. This shows that the analyzed system itself is stable and does not lead to a vicious-circle of reinforcing effects.

[17] The variables WAD1 and WAD2 were summarized in one variable WAD.

The Simulations "climate change", "demographic change" and "old relics" reflect typical mind models of the experts expressed in the interviews and workshops. The simulations "end of pipe policy" and "precautionary policy" reflect two opposing regulatory approaches. Based on the Fuzzy Cognitive Map, the modelled system is simulated. Table 6 illustrates the steady state as well as the final stable state of the simulation and the difference (Δ) of the latter two. In all simulations the system also reaches a stable state after max. 19 iterations.

Table 6: Simulations of the FCM

	steady state	Climate change	Δ	Demo-graphic change	Δ	*End-of pipe policy*	Δ	*Pre-cautio-nary policy*	Δ	*Old relics*	Δ
stormwater infiltration	0.6109	0.6507	0.0398	0.6090	-0.0019	*0.6109*	*0*	*0.6109*	*0*	0.5801	*-0.0308*
heat periods	0.5000	1	0.3891	*0.5000*	*-0.1109*	*0.5000*	*-0.1109*	*0.5000*	*-0.1109*	*0.5000*	*-0.1109*
decreasing water demand	0.4688	0.4073	-0.2036	1	0.3891	*0.4688*	*-0.1421*	*0.4688*	*-0.1421*	*0.4688*	*-0.1421*
seperate sewers	0.5993	0.6599	0.0490	0.5992	-0.0117	*0.5993*	*-0.0116*	*0.5993*	*-0.0116*	0.5975	*-0.0134*
sewer remediation needs	0.5603	0.5871	-0.0238	0.5927	-0.0182	*0.5603*	*-0.0506*	*0.5603*	*-0.0506*	1	*0.3891*
heavy rainfalls	0.5000	1	0.3891	*0.5000*	*-0.1109*	*0.5000*	*-0.1109*	*0.5000*	*-0.1109*	*0.5000*	*-0.1109*
short public budgets	0.4931	0.4906	-0.1203	0.5244	-0.0865	*0.4931*	*-0.1178*	*0.4931*	*-0.1178*	1	*0.3891*
ECONS	0.2355	0.1719	-0.4390	0.2035	-0.4074	0.1932	-0.4177	0.2649	-0.346	0.1643	-0.4466
SOCIS	0.5440	0.5010	-0.1099	0.5381	-0.0728	0.5362	-0.0747	0.5802	-0.0307	0.5308	-0.0801
ECOLS	0.7088	0.6456	0.0347	0.7390	0.1281	0.7459	0.135	0.7331	0.1222	0.6936	0.0827
population decrease	0.5000	*0.5000*	*-0.1109*	1	0.3891	*0.5000*	*-0.1109*	*0.5000*	*-0.1109*	*0.5000*	*-0.1109*
precautionary principle	0.5000	*0.5000*	*-0.1109*	*0.5000*	*-0.1109*	*0.5000*	*-0.1109*	1	0.3891	*0.5000*	-0.1109
regulation of agriculture	0.5312	0.5622	-0.0487	*0.5312*	*-0.0797*	*0.5312*	*-0.0797*	1	0.3891	*0.5312*	-0.0797
4th treatment stage	0.5581	0.5865	-0.0244	0.6481	0.0372	1	0.3891	0.4882	-0.1227	0.5581	-0.0528
drug residues	0.2459	0.2423	-0.3686	1	0.3891	0.1330	-0.4779	0.1979	-0.4130	0.2459	-0.3650
classical standards	0.4359	0.4340	-0.1769	*0.4359*	*-0.1750*	1	0.3891	0.3775	-0.2334	*0.4359*	-0.1750
phosphorus recycling	0.5374	0.5411	-0.0698	0.5374	-0.0735	*0.5374*	*-0.0735*	*0.5374*	*-0.0735*	0.5373	*-0.0736*

13.1.1 Climate Change

In the first simulation run, "climate change", the variables "heavy rainfalls" and "heat periods" are activated. See also Table 6. The comparison of the steady state and the final state of the climate change simulation shows the high impact of climate change on the sanitation system. Almost all variables except "population decrease" and "precautionary principle" have changed in the simulation. This is also due to the high outdegree of the two variables, and especially of the "heavy rainfall" variable. More frequent heavy rainfalls lead to an increasing need for a decentralized stormwater capture and storage (TCS3) and a further separation of the drain and sewer system (TCS5) which facilitates the recycling of phosphorus at the wastewater treatment plant (WWTP). The need to regulate agricultural pollutions increases because of the vulnerability of farmland to heavy rainfall. Following the evaluation of the participating experts, heat periods increase the need to increase the cleaning capacity (TCW1) which is lowering the need to increase classical cleaning standards and consequently lowering the accumulation of drug residues in the sewage. In the end the system is characterized by an increasing pressure on the local public budgets, and a decrease of the target variables ecological, economic, and social sustainability.

13.1.2 Demographic Change

In the second simulation, “demographic change”, the variables “decreasing water demand”, “population decrease”, and “drug residues” are activated. These three variables cover three important aspects discussed in Germany in relation to demographic change. Besides population decrease, the German society is also affected by an ageing population, which is suspected to reinforce the accumulation of drug residues in the sewage[18]. “Water demand” is expected to fall because of the lower number of inhabitants, but also due to a lower water demand per capita. The simulation shows that the increase of “drug residues” increases the need for a “4th treatment stage”. The decreasing “water demand” and population (DEM1) mainly limit further investments, such as “stormwater infiltration” and “separate sewers”. The “sewer remediation needs” in contrary are expected to increase. Variables concerning the purification standards (STA1, STA3, STA5) are not affected by demographic change in this simulation. Finally the economic burden leads to a lower economic sustainability and less customer satisfaction (SOCIS).

13.1.3 Precautionary Principle vs. End-of-Pipe

In the third simulation two different policy philosophies are analyzed, the precautionary approach is compared with a classical end-of-pipe approach. In the first simulation the variables “precautionary principle” and “regulation of agriculture” are activated, whereas in the end-of-pipe simulation “4th treatment stage” and “classical standards” are activated. Both simulations show that “drug residues” are reduced, but in the precautionary principle simulation this achievement goes hand in hand with an increase of all three aspects of sustainability whereas the end of pipe approach can increase the ecological sustainability only at the expense of a lower economic and social sustainability.

13.1.4 Old Relics

The fourth simulation, “old relics”, discusses the consequences of an insufficient maintenance of the sewer system and inappropriate budgeting and debt management (TCW4=FIN5=1). These bad management practices that might have been committed in the past are impairing those of the future generations. The simulation shows that investments in the infrastructure (TCS3 and TCS5) decrease. The lower financial capacities also reduce the possibility to invest for example in phosphorus recycling and installing a “4th treatment stage” which leads, as a consequence, to a slight increase of drug residues. All three aspects of sustainability decrease in this simulation. The “old relics” simulation shows that bad management practices limit adaptation options in the future.

13.2 Scenario building

In this chapter I will give an answer on RQ 2. Therefore, four scenarios are described. Based on the precedent analysis, I identified the most relevant future challenges and analyzed their interdependency. The first scenario, “Business-as-Usual”, incorporates the results of the FCM and the simulations. But in order to integrate the visionary statements of some experts ex-

[18] Recent research has shown that the increase of drug residues that can be found in German rivers [*Heberer,* 2002a; *Heberer,* 2002b] is less the result of demographic change, but of a steady increase of the volume of pharmaceuticals prescribed. [*Morgan,* 2006; *Royal Commission on Environmental Pollution,* 2011]

pressed in the interviews, I complete the Business-as-Usual scenario with three more visionary scenarios; "Watershed-First", "Recycling-First", and "Mega-City".

The scenario "Watershed-First" describes a future in which an alternative regulatory approach is applied. This scenario can be congruent with the existing central sanitation system, but it is also imaginable in combination with the following two scenarios. The "Recycling-First" and the "Mega-City" scenarios describe a future sanitation system that is fundamentally different to the existing central system and makes it mostly obsolete. The following Figure 5 illustrates the degree of change for each PESTE category in the four different scenarios.

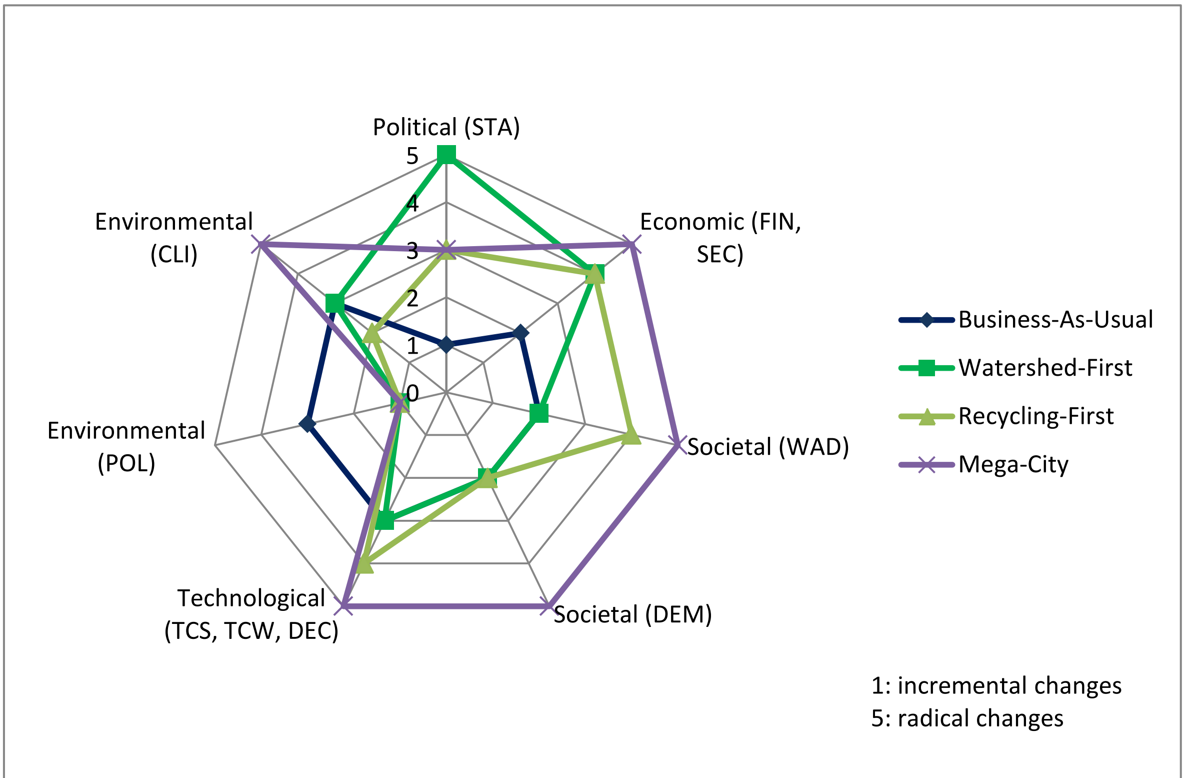


Figure 5: The four different scenarios and the differentiating PESTE categories

13.2.1 Business-as-Usual

In the "Business-as-Usual" scenario the existing system is principally maintained but challenged by external turbulences (see also simulations in chapter 13.1.1-13.1.4). The wastewater streams are collected via a central sewer system. Due to increased frequency of heavy rainfall caused by climate change (CLI1), the sewer system is separated into a drain and a sewer system. As much as possible, stormwater is collected, stored and infiltrated decentrally. New pollutants such as drug residues (POL1) will be removed by using a fourth treatment stage (TCW1). The wastewater treatment plant is developed as the central place for recycling, for example, of biomass and phosphorus (TCW6). Local farmers deliver biomass to the wastewater treatment plant. Phosphorus is recycled and used for fertilizer production. Increasing energy prices push forward the use of renewable energy (TCW3,4,7) on the wastewater treatment plant. The huge remediation needs (TCS4) are tackled by mainly trenchless restructuring methods (TCS2). This financial burden is financed by a reduction of subsidies for new constructions and a strict alignment on remediation (FIN6). The financial impacts of demographic change (DEM1) are counteracted by an adjustment of the wastewater rates, in the form of a basic rate in the amount of the fixed costs (FIN2). The water demand (WAD) is stabilized at 80 liters per capita and day. In a few peripheral settlements decentral and small wastewater treatment plants are installed, which are controlled via remote supervision under the management of the local sanitation utility. The predominant regulatory approach is the classical specification of standards (STA5). For a few specified pharmaceutical products the precautionary principle is applied (STA1), i.e. they are only licensed as a medical drug if they are degradable in water. In general, the sanitation utilities rise to the future challenges by a high degree of cooperation (SEC3). The high number of wastewater utilities is reduced by fusions and mergers of wastewater authorities. Purely public authorities integrate private knowledge by formal privatization (SEC2). Competition takes place only in a very limited indirect way (SEC4) between partial services, such as sewer cleaning.

13.2.2 Watershed-First

The "Watershed-First" scenario describes a possible future that emphasizes an ecological alignment of the regulatory regime and is principally consistent with the existing system but not necessarily. This scenario was based on the following expert statement:

> *"Until now the operator of the wastewater treatment plant has to fulfill specific quality standards at the final effluent discharge point. But a combined approach based on the emissions as well as on the immissions-principle would be more efficient, economically as well as ecologically. In the future, the operator has still to fulfill specific quality standards but this time on the watershed-level and he can decide whether he prefers to improve the technology on the wastewater treatment plant or an investment in stream morphology or other measures." (summarized, translated, analogous quote, similar statements in interview No. 9, 15 and 21)*

The main idea of this scenario is that "water agencies" (to be established) manage the entire watershed (STA2), i.e. water as well as wastewater services are combined in one integrated agency (FIN2). It is in the responsibility of the water agency to achieve specified management goals (e.g. water quality goals). The water agencies need to apply with their management plans during a bidding procedure that is repeated every ten years. In this scenario the water agency is in direct competition (SEC5) during the bidding procedure. In the management plans the agency can freely decide whether they invest in wastewater treatment technologies (TCW1) or pursue alternative approaches such as payments for environmental services to motivate farmers to reduce pollution from diffuse sources (STA3). Pollution-depending charging (FIN4) might be implemented in some hot spots where a high degree of pollution (POL2,3,4,5) and sensitive receiving waters come into conflict. It is also in the responsibility of the water agency to decide whether settlements are connected to a central sewer system or to small and decentral systems (DEC2).

13.2.3 Recycling-First[19]

The primary concern of the recycling-first scenario is the highest possible degree of recycling of nutrients at a household level as described in Hiessl et al. [2002].This can be achieved by

[19] This scenario is also described by Hiessl et al. [2002] in a comparable way.

rainwater harvesting, grey water recycling and the separation of wastewater streams. Greywater is used for gardening and washing. Yellowwater is used for the production of fertilizers and separated in urine diversion toilets (DEC1). Brownwater and organic waste is used for energy production. The used technology is mainly based on on-site treatment technologies, e.g. membrane technology (DEC2). Water demand (WAD) decreases significantly (<60 liters per capita and day).

> *"We have already today technologies that allow us to reduce the water consumption drastically, for example: vacuum toilets, the 15 liter shower or the 2.5 liter dishwasher. The question here is much more, if the technology is accepted by the end-user. In the short run this technology is mostly interesting for rural areas, development areas and major green real estate projects." (summarized, translated and analogous quote, similar statements in interviews No. 3, 9 and 12)*

The regulatory idea behind this scenario is mainly the polluter-pays-principle, whereas rising energy and commodity prices make it more and more financially attractive to recycle the wastewater streams. Thus, the most important driver for this scenario is, besides the financial burden of "Old Relics" (FIN5) and the financial consequences of demographic change (DEM1), an increasing scarcity of resources and energy, pushing energy and commodity prices such as phosphorus (DEC1). The central system is obsolete in the outskirts and low populated areas but maintained in densely populated settlements leading to direct competition between central and decentralized systems (SEC5) in the overlapping area. See Figure 6 for an illustration of the "Recycling-First" scenario.

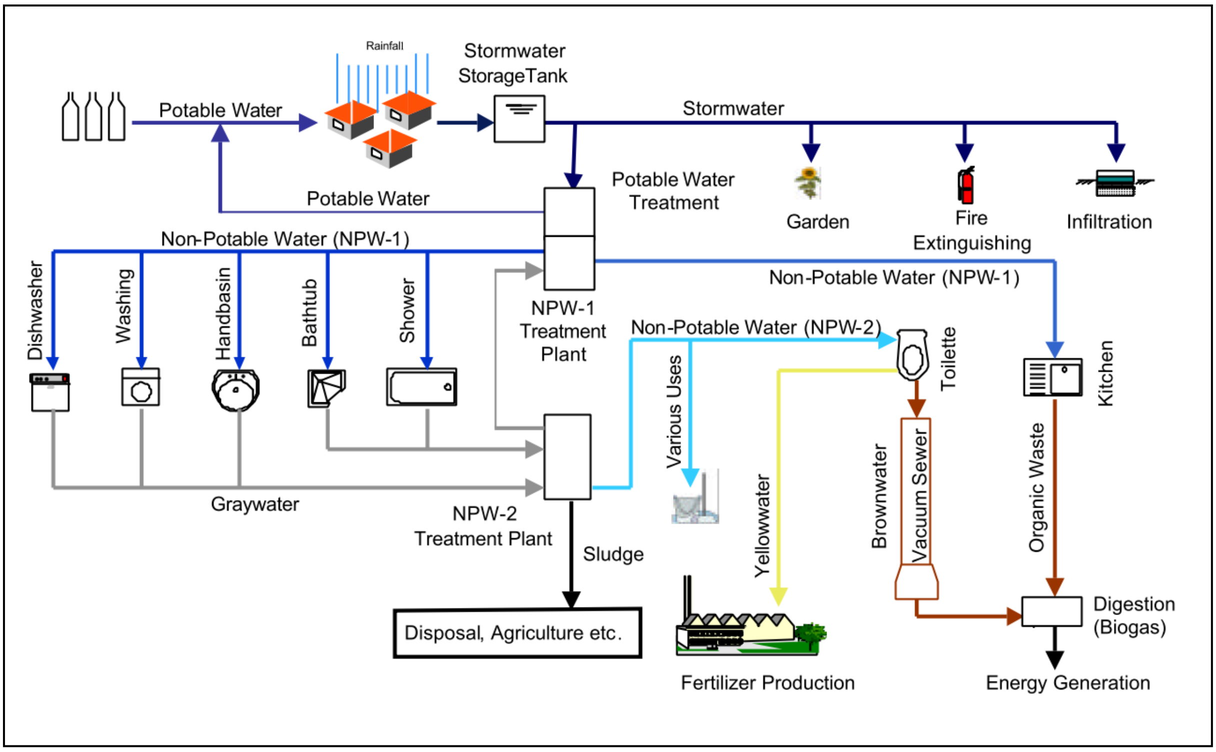


Figure 6: Illustration of the "Recycling-First" scenario (source: [Hiessl et al. 2002])

13.2.4 Mega-City

The “Mega-City” scenario describes a further development of the “Recycling-First” scenario. Due to an extreme urbanization and, in these areas, high population growth (DEM1), the water demand (WAD) cannot be satisfied by the usual sources. Therefore a fixed yearly water allocation is apportioned to each inhabitant. As this allocation covers only the necessary amount of drinking water, water needs to be recycled as in the “Recycling-First” scenario, but in this scenario also in areas of high population density. Rain water harvesting, closed water cycles, and cascade-use of water are implemented on building level. Wastewater is purified and used several times (DEC2). Large buildings are constructed in such a way that they can supply themselves with water and energy. [*Varis et al.*, 2006][20] Water and energy prices increase drastically (FIN), making the on-site infrastructure financially attractive. This scenario is first realized in megacities of the fast growing and developing countries and in the following also implemented in Germany.

> *“Especially in the fast growing urban centers in the developing and transition countries new decentralized technologies and closed-loop water system will be employed. First, Germany’s industry will only deliver necessary technology but it is possible that in the far future these technologies will also be put into practice one day in Germany.” (summarized, translated and analogous quote, interviews similar statements in interview No. 9 and 12)*

14 Discussion

Reflecting my methodology, I would like to highlight four aspects concerning the interviews, the expert workshop, the degree of expert participation and the scenario development.

The expert interviews turned out to be especially fruitful. Contentious uncertainties could be removed during the interviews, negative impacts of group communication processes could be avoided, and weak signals such as POL1 could be identified. The anonymity of the interview and of Delphi technique played a crucial role here.

The expert workshop, in which the Fuzzy Cognitive Map was drawn, was also highly productive. Alternatively to the top 15 challenges, a backcasting approach might allow the sanitation professionals to overcome the capability gap by asking them how a sustainable sanitation sector in the year 2050 might look like, and what is necessary to reach this goal. This might support the sanitation professionals to overcome their usual mind-models and to enhance creativity.

I combined a workshop, interviews, an online survey and an online discussion board to assure a high degree of participation in order to facilitate a conversation and to allow experts to generate ideas in view of the responses of the other experts. Each part has had its own strengths and weaknesses. During the workshop the motivation of the participants was very high, but was mostly attractive for experts or sanitation professionals from the region. Here the integration of the workshop within a major conference is worth considering. This way the motivation of experts from other regions to attend to the workshop might be higher. The high response

[20] This concept is extended to food by Despommier [2008; 2011].

rate of the online survey also has proven its attractiveness for the experts and is definitely recommendable. Worth considering is also the use of existing social networks for a Delphi study. The use of already existing professional social networks assures a high degree of internet affinity and possibly also a high degree of participation in online surveys.

The Business-as-Usual scenario was completed by three explorative scenarios which were built up on three visionary expert statements. The election of the expert statements was conducted as objectively as possible, but finally based on the author's decision. My recommendation is to assess in future research how Fuzzy Cognitive Maps can contribute to develop explorative scenarios, that are characterized by a long range time horizon and challenges that are beyond the Business-as-Usual scenario.

Finally, the new Delphi-based scenario methodology that was tested and presented here facilitates to develop more objective and more creative scenarios.

15 Conclusions

The goal of this research article was to identify possible future challenges, to which the sanitation sector in Germany has to be prepared for in the year 2050 (RQ1) and to illustrate possible future states of the sanitation sector in Germany (RQ2).

I could answer the first research question (RQ1) in chapter 3.1. The results illustrate comprehensively possible future challenges, which might affect the sanitation sector in the future. I also provided an evaluation of the relevance of the specific challenges. The catalogue of identified challenges can be used by operators of sanitation utilities and decision-makers in the sector as a checklist within their strategic planning activities and for an intensive risk analysis, evaluating their utility specific vulnerability. For the research community the catalogue offers a perfect starting point for future research programs, which might investigate in more detail, for example, how the sanitation sector should deal with drug residues.

An answer to the second research question (RQ2) was given in chapter 13.2, where the Business-as-Usual scenario was completed by three explorative scenarios reflecting three possible future states of the sanitation sector in Germany in the year 2050. All three explorative scenarios are a valuable starting point for strategic planning activities for the authorities as well as for operators of the wastewater utilities. I recommend using the scenarios in strategic planning workshops as a starting point in order to assure an efficient scenario transfer and, consequently, to derive the necessary decisions that are adequate to the long life span of the infrastructure.

In view of the manifold challenges, decision-makers in the sanitation sector need to close the capability gap and to increase its adaptive capacity. As I have shown in this article, scenario planning offers a valuable instrument to close this gap and thereby increase the adaptive capacity of the sanitation sector.

Appendix

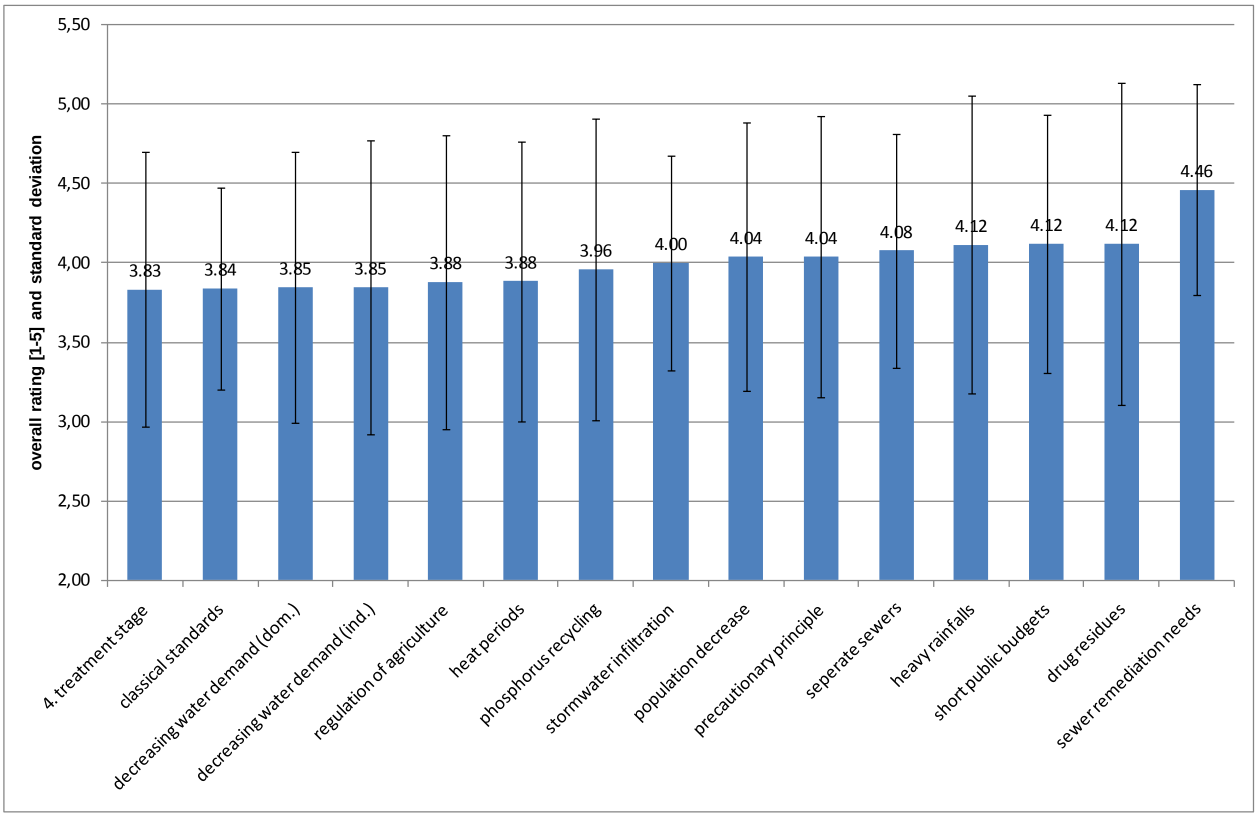


Figure 7: Top 15 future challenges

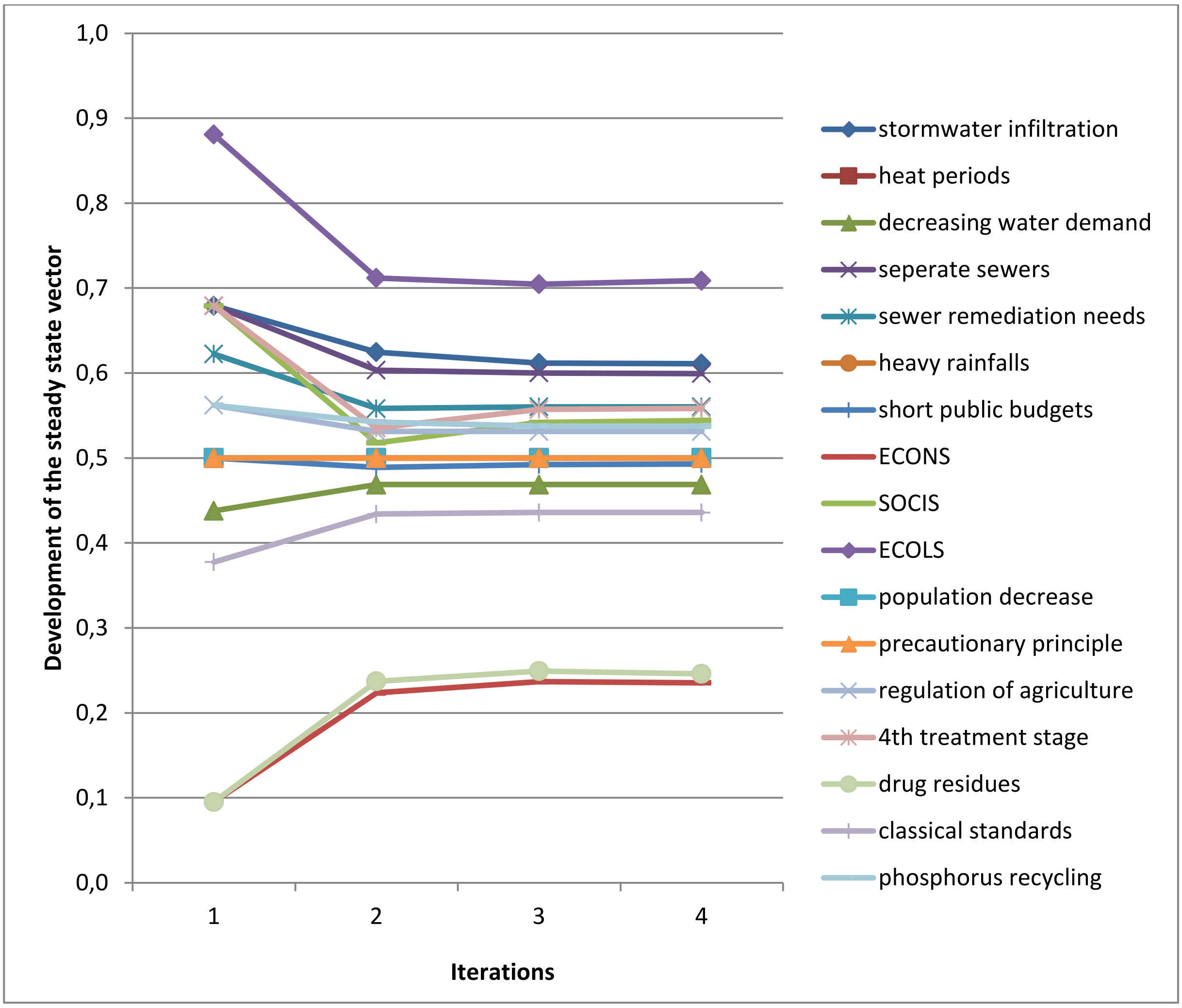


Figure 8: Development of the steady state vector

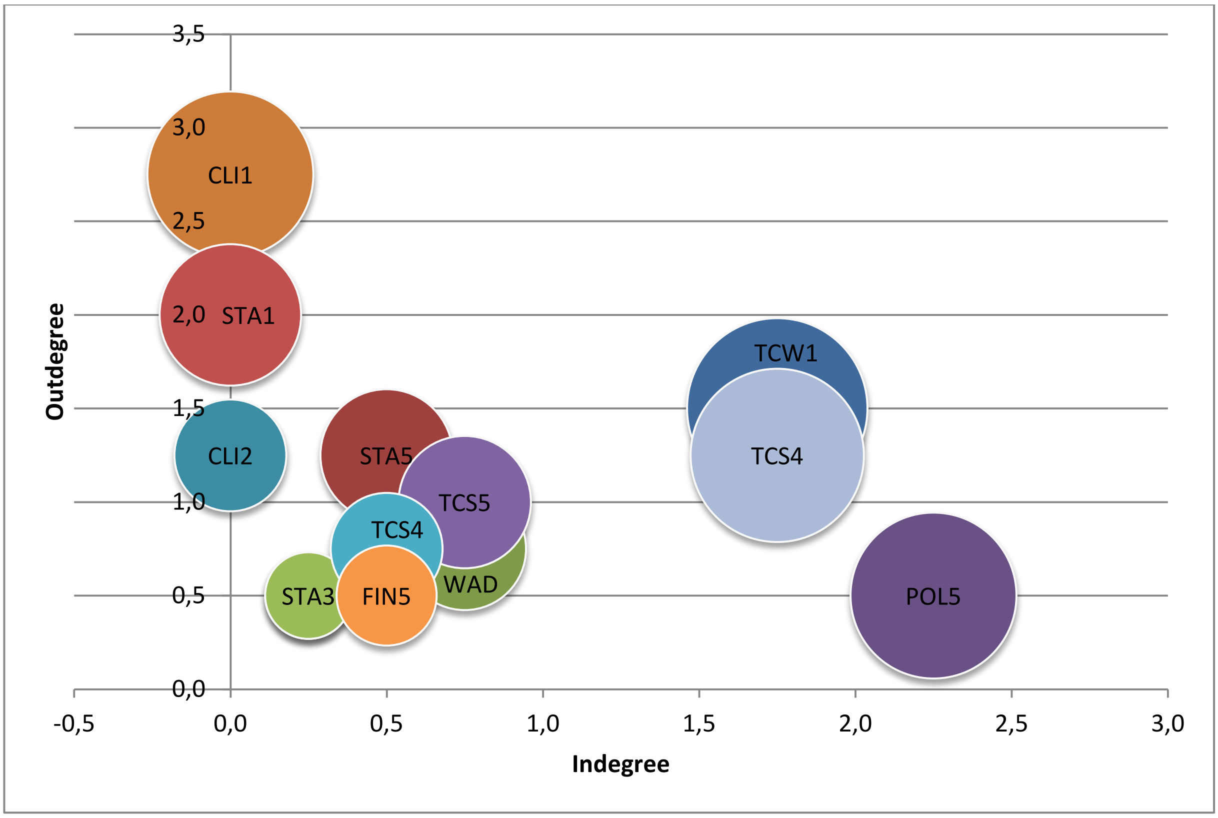


Figure 9: Illustration of the outdegree, indegree and centrality of the FCM variables

References

Bañuls, V. A., and M. Turoff (201X), Scenario construction via Delphi and cross-impact analysis, *Technol. Forecast. Soc. Change, In Press, Corrected Proof*, doi: 10.1016/j.techfore.2011.03.014.

Bates, B. C., Z. W. Kundzewicz, S. Wu, and J. P. Palutikof (Eds.) (2008), *Climate Change and Water: Technical Paper of the Intergovernmental Panel on Climate Change*, 210 pp., IPCC Secretariat, Geneva.

Baur, R., and R. Herz (2002), Selective inspection planning with aging forecast for sewer types, *Water Sci. Technol.*, *46*(6), 389-396, doi: www.iwaponline.com/wst/04606/wst046060389.htm.

Berkhout, F., J. Hertin, and D. Gann (2006), Learning to Adapt: Organisational Adaptation to Climate Change Impacts, *Clim. Change*, *78*(1), 135-156, doi: 10.1007/s10584-006-9089-3.

Bishop, P., A. Hines, and T. Collins (2007), The current state of scenario development: An overview of techniques, *Foresight*, *9*(1), 5-25, doi: 10.1108/14636680710727516.

Börjeson, L., M. Höjer, K. Dreborg, T. Ekvall, and G. Finnveden (2006), Scenario types and techniques: Towards a user's guide, *Futures*, *38*(7), 723-739, doi: 10.1016/j.futures.2005.12.002.

Bradfield, R., G. Wright, G. Burt, G. Cairns, and K. Van Der Heijden (2005), The origins and evolution of scenario techniques in long range business planning, *Futures*, *37*(8), 795-812, doi: 10.1016/j.futures.2005.01.003.

Caille, F., J. L. Riera, B. Rodríguez-Labajos, H. Middelkoop, and A. Rosell-Melé (2007), Participatory scenario development for integrated assessment of nutrient flows in a Catalan river catchment, *Hydrol. Earth Syst. Sci. Discuss.*, *4*(3), 1265-1299, doi: doi:10.5194/hessd-4-1265-2007.

Chenoweth, J. L., and W. Wehrmeyer (2006), Scenario development for 2050 for the Israeli/Palestinian water sector, *Popul. Environ.*, *27*(3), 245-261, doi: 10.1007/s11111-006-0021-6.

Chermack, T. J., and L. Van Der Merwe (2003), The role of constructivist learning in scenario planning, *Futures*, *35*(5), 445-460, doi: 10.1016/S0016-3287(02)00091-5.

Chermack, T. J., S. A. Lynham, and W. E. A. Ruona (2001), A Review of scenario planning literature, *Futures Res. Q.*, *17*(2), 7-31, doi: www.cse.buffalo.edu/~peter/refs/DataAssimilation/Multihypothesis/ReviewofSP.PDF.

Christoph, M., A. Fink, B. Diekkruger, S. Giertz, B. Reichert, and P. Speth (2008), IMPETUS: Implementing HELP in the upper Ouémé basin, *Water SA*, *34*(4 SPEC. ISS.), 481-489, doi: www.wrc.org.za.

Cornelius, P., M. Romani, and A. Van De Putte (2005), Three Decades of Scenario Planning in Shell, *Calif. Manage. Rev.*, *48*(1), 95-109, doi: 10.1225/CMR326.

De Jong, R. L., H. Yazicigil, and R. I. Al-Layla (1989), Scenario planning for water resources: a Saudi Arabian case study, *Water Int.*, *14*(1), 6-12, doi: 10.1080/02508068908692025.

Despommier, D. (2008), The Vertical Farm, *Property Australia*, *23*, 30-34.

Despommier, D. (2011), *The Vertical Farm Feeding the World in the 21st Century*, 320 pp., Thomas Dunne Books, New York.

Dominguez, D., and W. Gujer (2006), Evolution of a wastewater treatment plant challenges traditional design concepts, *Water Research*, *40*(7), 1389-1396, doi: 10.1016/j.watres.2006.01.034.

Dominguez, D., H. Worch, J. Markard, B. Truffer, and W. Gujer (2009), Closing the Capability Gap: Strategic Planning for the Infrastructure Sector, *Calif. Manage. Rev.*, *51*(2), 30-50, doi: DOI: 10.1225/CMR417.

European Parliament and European Council (2000), EU Water Framework Directive, *EC of the European Parliament and of the Council, 23/10/2000*.

Fassin, Y. (2009), The stakeholder model refined, *J. Bus. Ethics*, *84*(1), 113-135, doi: 10.1007/s10551-008-9677-4.

Federal Government of Germany (1990), Televised speech by chancellor Kohl on the occasion of the entry into force of the economic, monetary and social union on 1 July 1990, *Bulletin des Presse- und Informationsamts der Bundesregierung Nr. 86 (3. 07. 1990), 2011*.

Federal Statistical Office of Germany (2010), *Statistical Yearbook 2010: For the Federal Republic of Germany*, 745 pp., Federal Statistical Office of Germany, Wiesbaden.

Freeman, R. E. (2010), *Strategic Management: A Stakeholder Approach*, 292 pp., Cambridge University Press, Cambridge.

Galer, G. S. and K. van der Heijden (2001), Scenarios and their contribution to organizantional learning: From practice to theory, in *Handbook of Organizational Learning and Knowledge*, edited by M. Dierkes, pp. 849-864, Oxford Univ. Press, Oxford.

German Advisory Council on Global Change (Ed.) (1997), *World in Transition: Ways Towards Sustainable Management of Freshwater Resources*, vol. Flagship Report 1997, 392 pp., Springer Verlag, Berlin.

Godet, M. (2000), The Art of Scenarios and Strategic Planning: Tools and Pitfalls, *Technol. Forecast. Soc. Change*, *65*(1), 3-22, doi: 10.1016/S0040-1625(99)00120-1.

Goodwin, P., and G. Wright (2001), Enhancing strategy evaluation in scenario planning: a role for decision analysis, *J. Manage. Stud.*, *38*(1), 1-16, doi: 10.1111/1467-6486.00225.

Gordon, T., and A. Pease (2006), RT Delphi: An efficient, “round-less” almost real time Delphi method, *Technol. Forecast. Soc. Change.*, *73*(4), 321-333, doi: 10.1016/j.techfore.2005.09.005.

Grienitz, V., A. Schmidt, and A. Schmidt (2010), Scenariobased Complexity Management by adapting the Methods of Social Network Analysis, paper presented at The International Multi-Conference on Complexity, Informatics and Cybernetics, IMCIC 2010, Orlando, Florida.

Grienitz, V. and A. -. Schmidt (2010), Scenariobased Complexity Management by adapting the Methods of Social Network Analysis, Orlando, Florida.

Gupta, U. G., and R. E. Clarke (1996), Theory and applications of the Delphi technique: A bibliography (1975–1994), *Technol. Forecast. Soc. Change, 53*(2), 185-211, doi: 10.1016/S0040-1625(96)00094-7.

Hatzilacou, D., G. Kallis, A. Mexa, H. Coccosis, and E. Svoronou (2007), Scenario workshops: A useful method for participatory water resources planning?*, Water Resour. Res., 43*(6), W06414.

Heberer, T. (2002a), Occurrence, fate, and removal of pharmaceutical residues in the aquatic environment: a review of recent research data, *Toxicol. Lett., 131*(1-2), 5-17, doi: 10.1016/S0378-4274(02)00041-3.

Heberer, T. (2002b), Tracking persistent pharmaceutical residues from municipal sewage to drinking water, *J. Hydol., 266*(3-4), 175-189, doi: 10.1016/S0022-1694(02)00165-8.

Hiessl, H., and D. Toussaint (1999), Szenarios für Stadtentwässerungs-Systeme, *Ecol. Persp. Sci. , Humanities & Econ., 8*(3), 176-185.

Hiessl, H., R. Wals, and D. Toussaint (2002), Design and sustainability assessment of scenarios of urban water infrastructure systems, paper presented at 5th International Conference on Technology Policy and Innovation: Critical Infrastructures, Utrecht, the Netherlands.

Hill, K. Q., and J. Fowles (1975), The methodological worth of the Delphi forecasting technique, *Technol. Forecast. Soc. Change, 7*(2), 179-192, doi: 10.1016/0040-1625(75)90057-8.

Hillenbrand, T., J. Niederste-Hollenberg, E. Menger-Krug, S. Klug, R. Holländer, S. Lautenschläger, S. Geyler, U. Winkler, S. Geisler, and T. Völkner (2010), Demographic change as a challenge to secure and develop cost- and resource-efficient wastewater infrastructur, *Texte, 36/2010*, 1-253, doi: www.umweltdaten.de/publikationen/fpdf-l/3779.pdf, Umweltbundesamt, Dessau-Roßlau.

Hogarth, R. M., and S. Makridakis (1981), Forecasting and planning: An evaluation, *Manage. Sci., 27*(2), 115-138, doi: 10.1287/mnsc.27.2.115.

Huff, A. S. (1999), *Writing for Scholarly Publication*, 185 pp., Sage Publications, Thousand Oaks, Calif.

Huff, A. S. (2008), *Designing Research for Publication*, 392 pp., Sage Publications, Inc, Los Angeles, London, New Delhi, Singapore.

Huitema, D. and S. Meijerink (2007), Understanding and managing water transitions: a policy science perspective, paper presented at Amsterdam Conference on Earth System Governance, Amsterdam, the Netherlands, Amsterdam.

Hummel, D., and A. Lux (2007), Population decline and infrastructure: The case of the German water supply system, *Vienna Yearb. Popul. Res.*, 167-191, doi: 10.1553/populationyearbook2007s167.

Ingram, H. and L. Fraser (2006), Path dependency and adroit innovation: The case of california water, in *Punctuated Equilibrium and the Dynamics of US Environmental Policy*, edited by R. Repetto, pp. 78-109, Yale University Press, New Haven.

International Food Policy Research Institute (Ed.) (2002), *World Water and Food to 2025: Dealing with Scarcity*, 322 pp., International Food Policy Research Institute (IFPRI), Washington, D.C.

International Water Management Institute (Ed.) (2007), *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*, 645 pp., Earthscan, London; Sterling, VA.

IPCC Working Group III (Ed.) (2000), *Special Report on Emissions Scenarios*, 612 pp., Cambridge University Press, New York.

Jessel, B., and J. Jacobs (2005), Land use scenario development and stakeholder involvement as tools for watershed management within the Havel River Basin, *Limnologica, 35*(3), 220-233, doi: 10.1016/j.limno.2005.06.006.

Jetter, A., and W. Schweinfort (2011), Building scenarios with Fuzzy Cognitive Maps: An exploratory study of solar energy, *Futures, 43*(1), 52-66, doi: 10.1016/j.futures.2010.05.002.

Kaempfer, W. and M. Berndt (1999), Estimation of service life of concrete pipes in sewer networks, in *Durability of Building Materials & Components 8: Service Life and Asset Management*, vol. 1, edited by M. A. Lacasse and D. J. Vanier, pp. 36-46, NRC Research Press, Ottawa, Canada.

Kahn, H. (1960), *On Thermonuclear War*, 668 pp., Princeton Univ. Pr., Princeton.

Kahn, H. and A. J. Wiener (1967), *The Year 2000: A Framework for Speculation on the Next Thirty-Three Years*, 432 pp., Macmillan, New York.

Kindler, H. S. (1979), Two planning strategies: Incremental change and transformational change, *Group. Organ. Manage., 4*(4), 476-484, doi: 10.1177/105960117900400409.

Kirkpatrick, C., D. Parker, and Y. F. Zhang (2006), State versus Private Sector Provision of Water Services in Africa: An Empirical Analysis, *World Bank Econ. Rev., 20*(1), 143-163, doi: 10.1093/wber/lhj001.

Kok, K., M. van Vliet Mathijs, I. Bärlund Ilona, A. Dubel, and J. Sendzimir (2011), Combining participative backcasting and exploratory scenario development: Experiences from the SCENES project, *Technol. Forecast. Soc. Change, 78*(5), 835-851, doi: 10.1016/j.techfore.2011.01.004.

Kok, K. (2009), The potential of Fuzzy Cognitive Maps for semi-quantitative scenario development, with an example from Brazil, *Global Environ. Change, 19*(1), 122-133, doi: 10.1016/j.gloenvcha.2008.08.003.

Kosko, B. (1986), Fuzzy cognitive maps, *Int. J. Man. Mach. Stud., 24*(1), 65-75, doi: 10.1016/S0020-7373(86)80040-2.

Kraemer, R. A. and W. Hansen (2004), *International Comparison of Water Sectors: Comparison of Systems Against a Background of European and Economic Policy*, 139 pp., Bundeskammer für Arbeiter und Angestellte, Wien.

Kuusi, O., and M. Meyer (2002), Technological generalizations and leitbilder—the anticipation of technological opportunities, *Technol. Forecast. Soc. Change, 69*(6), 625-639, doi: 10.1016/S0040-1625(02)00182-8.

Landeta, J. (2006), Current validity of the Delphi method in social sciences, *Technol. Forecast. Soc. Change, 73*(5), 467-482, doi: 10.1016/j.techfore.2005.09.002.

Leibenstein, H. (1950), Bandwagon, snob, and Veblen effects in the theory of consumers demand, *Q. J. Econ., 64*(2), 183-207, doi: www.jstor.org/stable/1882692.

Lemer, A. C. (1996), Infrastructure obsolescence and design service life, *J. Infrastruct. Syst., 2*(4), 153-161, doi: 10.1061/(ASCE)1076-0342(1996)2:4(153).

Lempert, R., S. Hoorens, M. Hallworth, and T. Ling (2009), *Looking Back on Looking Forward: A Review on Evaluative Scenario Literature*, 28 pp., European Environment Agency, Copenhagen.

Lienert, J., J. Monstadt, and B. Truffer (2006), Future scenarios for a sustainable water sector: A case study from Switzerland, *Environ. Sci. Technol., 40*(2), 436-442, doi: 10.1021/es0514139.

Linstone, H. A. (1975), Eight basic pitfalls: A checklist in the delphi method, in *The Delphi Method: Techniques and Applications*, edited by H. A. Linstone and M. Turoff, pp. 573-586, Addison-Wesley Publ., Reading/Mass.

Linstone, H. A. and M. Turoff (1975), *The Delphi Method: Techniques and Applications*, 621 pp., Addison-Wesley Publ., Reading/Mass.

Loveridge, D. (1999), Foresight and Delphi processes as information sources for scenario planning, *Ideas in Progress Paper, Paper Number 11, Ideas in Progress*, 1-11, doi: http://phps.portals.mbs.ac.uk/Portals/49/docs/dloveridge/iirconfpdf_wp11.PDF.

Mahmoud, M. I., H. V. Gupta, and S. Rajagopal (2011), Scenario development for water resources planning and watershed management: Methodology and semi-arid region case study, *Environ. Model. Softw., 26*(7), 873-885, doi: 10.1016/j.envsoft.2011.02.003.

Malaska, P., M. Malmivirta, T. Meristo, and S. Hansen (1984), Scenarios in Europe - who uses them and why?, *Long Range Plann, 17*(5), 45-49, doi: 10.1016/0024-6301(84)90036-0.

Martelli, A. (2001), Scenario building and scenario planning: state of the art and prospects of evolution, *J. Futures Res. Q., 17*(3), 57-74.

Means, E., L. Ospina, and R. Patrick (2005a), Ten primary trends and their implications for water utilities, *J. Am. Water Works Assoc., 97*(7), 64-77.

Means, E., R. Patrick, L. Ospina, and N. West (2005b), Scenario planning: A tool to manage future water utility uncertainty, *J. Am. Water Works Assoc.*, *97*(10), 68-75.

Mietzner, D., and G. Reger (2005), Advantages and disadvantages of scenario approaches for strategic foresight, *Int. J. Technol. Intelligence and Plann*, *1*(2), 220-239, doi: 10.1504/IJTIP.2005.006516.

Miller, D., and P. H. Friesen (1982), Structural change and performance: Quantum versus piecemeal-incremental approaches, *Acad. Manage. J.*, *25*(4), 867-892, doi: 10.2307/256104.

Miller, K. D., and H. G. Waller (2003), Scenarios, Real Options and Integrated Risk Management, *Long Range Plann.*, *36*(1), 93-107, doi: 10.1016/S0024-6301(02)00205-4.

Millett, S. M. (2003), The future of scenarios: challenges and opportunities, *Strategy Leadersh.*, *31*(2), 16-24, doi: 10.1108/10878570310698089.

Morgan, S. G. (2006), Prescription drug expenditures and population demographics, *Health Serv. Res.*, *41*(2), 411-428, doi: 10.1111/j.1475-6773.2005.00495.x.

Nedeva, M., L. Georghiou, D. Loveridge, and H. Cameron (1996), The use of co-nomination to identify expert participants for Technology Foresight, *R&D Manage.*, *26*(2), 155-168, doi: 10.1111/j.1467-9310.1996.tb00939.x.

Nowack, M., S. John, J. Tränckner, and E. Günther (2010), Demographic Change as Driver of Wastewater fees in Urban Drainage Systems – A Comparison of Demography, Water Saving, Maintenance Cost, Operating Cost and Industry Effects, *gwf*, *2010*, 1076-1085.

Nowack, M., J. Endrikat, and E. Guenther (2011), Review of Delphi-based scenario studies: Quality and design considerations, *Technol. Forecast. Soc. Change*, doi: 10.1016/j.techfore.2011.03.006, In Press, Corrected Proof.

O'Connor, M. H., M. McFarlane, J. Fisher, D. MacRae, and T. Lefroy (2005), The Avon River Basin in 2050: Scenario planning in the Western Australian Wheatbelt, *Aust. J. Agric. Res.*, *56*(6), 563-580, doi: 10.1071/AR04195.

OECD (2007), *Infrastructure to 2030. Vol. 2: Mapping Policy for Electricity, Water and Transport*, 506 pp., Organisation for Economic Cooperation and Development (OECD), OECD Publ.;, Paris.

OECD (2008), *OECD Environmental Outlook to 2030*, 520 pp., Organisation for Economic Cooperation and Development (OECD); OECD Publishing;, Paris.

OECD (2009), *Managing Water for all: An OECD Perspective on Pricing and Financing*, 149 pp., Organisation for Economic Cooperation and Development (OECD); OECD Publishing;, Paris.

Özesmi, U., and S. L. Özesmi (2004), Ecological models based on people’s knowledge: a multi-step fuzzy cognitive mapping approach, *Ecol. Model.*, *176*(1-2), 43-64, doi: 10.1016/j.ecolmodel.2003.10.027.

Papageorgiou, E., C. Stylios, and P. Groumpos (2003), Fuzzy cognitive map learning based on nonlinear hebbian rule, in *AI 2003: Advances in Artificial Intelligence*, vol. 2903, edited by Tamás Gedeon and Lance Fung, pp. 256-268, Springer, Berlin.

Phelps, R., C. Chan, and S. C. Kapsalis (2001), Does scenario planning affect performance? Two exploratory studies, *J. Bus. Res., 51*(3), 223-232, doi: 10.1016/S0148-2963(99)00048-X.

Pierson, P. (2000), Increasing returns, path dependence, and the study of politics, *Am. Polit. Sci. Rev., 94*(2), 251-267, doi: www.jstor.org/stable/2586011.

Porter, M. E. (1985), *Competitive Advantage*, vol. 15, 557 pp., Free Press, New York.

Porter, M. E. (2008), The five competitive forces that shape strategy, *Harv. Bus. Rev., 86*(1), 78-93, doi: 10.1225/R0801E.

Rees, J. A. (1998), Regulation and private participation in the water and sanitation sector, *Nat. Res. Forum, 22*(2), 95-105, doi: 10.1111/j.1477-8947.1998.tb00717.x.

Reimann, S. (1998), On the design of artificial auto-associative neuronal networks, *Neural Networks, 11*(4), 611-621, doi: 10.1016/S0893-6080(98)00001-X.

Rikkonen, P., and P. Tapio (2009), Future prospects of alternative agro-based bioenergy use in Finland—Constructing scenarios with quantitative and qualitative Delphi data, *Technol. Forecast. Soc. Change, 76*(7), 978-990, doi: 10.1016/j.techfore.2008.12.001.

Rossel, P. (2009), Weak Signals as a Flexible Framing Space for Enhanced Management and Decision-Making, *Technol. Anal. Strateg. Manage., 21*(3), 307-320, doi: 10.1080/09537320902750616.

Rowe, G., and G. Wright (1999), The Delphi technique as a forecasting tool: issues and analysis, *Int. J. Forecast., 15*(4), 353-375, doi: 10.1016/S0169-2070(99)00018-7.

Royal Commission on Environmental Pollution (Ed.) (2011), *Demographic Change and the Environment*, Royal Commission Report, vol. 29, 128 pp., The UK Stationery Office, London.

Royal Dutch Shell (Ed.) (2005), *The Shell Global Scenarios to 2025 - the Future Business Environment: Trends, Trade-Offs and Choices*, 220 pp., Royal Dutch/Shell Group, London.

Saritas, O., and J. E. Smith (2011), The Big Picture – trends, drivers, wild cards, discontinuities and weak signals, *Futures, 43*(3), 292-312, doi: 10.1016/j.futures.2010.11.007.

Schlör, H., J. Hake, and W. Kuckshinrichs (2009), Demographics as a new challenge for sustainable development in the German wastewater sector, *Int. J. Envir. Sustain. Dev., 10*(3-4), 327-352, doi: 10.1504/IJETM.2009.023738.

Schnaars, S. P. (1987), How to develop and use scenarios, *Long Range Plann., 20*(1), 105-114, doi: 10.1016/0024-6301(87)90038-0.

Schnaars, S., and P. L. Ziamou (2001), The essentials of scenario writing, *Bus. Horiz., 44*(4), 25-31, doi: 10.1016/S0007-6813(01)80044-6.

Schoemaker, P. J. H. (1991), When and how to use scenario planning: A heuristic approach with illustration, *J. Forecast.*, *10*(6), 549-617, doi: 10.1002/for.3980100602.

Schoemaker, P. J. H. (1993), Multiple Scenario Development: its Conceptual and Behavioral Foundation, *Strategic Manage. J.*, *14*(3), 193-213, doi: 10.1002/smj.4250140304.

Schoemaker, P. J. H. (1995), Scenario Planning: A Tool for Strategic Thinking, *Sloan Manage. Rev.*, *36*(2), 25-40.

Schwartz, P. (1998), *The Art of the Long View: Planning for the Future in an Uncertain World*, 258 pp., Wiley & Sons, Chichester.

Shell International (2010), Looking ahead: scenarios - About Shell, *2010*(10/23/2010).

Slaughter, R. A. (2002a), From forecasting and scenarios to social construction: changing methodological paradigms in futures studies, *Foresight*, *4*(3), 26-31, doi: 10.1108/14636680210697731.

Slaughter, R. A. (2002b), Futures studies as a civilizational catalyst, *Futures*, *34*(3-4), 349-363, doi: 10.1016/S0016-3287(01)00049-0.

Soboll, A., M. Elbers, R. Barthel, J. Schmude, A. Ernst, and R. Ziller (2011), Integrated regional modelling and scenario development to evaluate future water demand under global change conditions, *Mitigation Adapt. Strateg. Global Change*, *16*(4), 477-498, doi: 10.1007/s11027-010-9274-6.

Steinert, M. (2009), A dissensus based online Delphi approach: An explorative research tool, *Technol. Forecast. Soc. Change*, *76*(3), 291-300, doi: 10.1016/j.techfore.2008.10.006.

Störmer, E. et al. (2009), The exploratory analysis of trade-offs in strategic planning: Lessons from Regional Infrastructure Foresight, *Technol. Forecast. Soc. Change*, *76*(9), 1150-1162, doi: 10.1016/j.techfore.2009.07.008.

Straatsma, M., A. Schipper, M. van der Perk, C. van den Brink, R. Leuven, and H. Middelkoop (2009), Impact of value-driven scenarios on the geomorphology and ecology of lower Rhine floodplains under a changing climate, *Landsc. Urban Plann.*, *92*(2), 160-174, doi: 10.1016/j.landurbplan.2009.04.004.

Straton, A. T., S. Jackson, O. Marinoni, W. Proctor, and E. Woodward (2010), Exploring and Evaluating Scenarios for a River Catchment in Northern Australia Using Scenario Development, Multi-criteria Analysis and a Deliberative Process as a Tool for Water Planning, *Water Resour. Manage.*, *25*(1), 141-164, doi: 10.1007/s11269-010-9691-z.

Tapio, P. (2002), Disaggregative policy Delphi: Using cluster analysis as a tool for systematic scenario formation, *Technol. Forecast. Soc. Change.*, *70*(1), 83-101, doi: 10.1016/S0040-1625(01)00177-9.

Turoff, M. (1970), The design of a policy Delphi, *Technol. Forecast. Soc. Change.*, *2*(2), 149-171, doi: 10.1016/0040-1625(70)90161-7.

Turoff, M. (1975), The policy delphi, in *The Delphi Method: Techniques and Applications*, edited by H. A. Linstone and M. Turoff, pp. 84-101, Addison-Wesley Publ., Reading, Mass.

Tversky, A., and D. Kahneman (1974), Judgment under uncertainty: Heuristics and Biases, *Sci., 185*, 1124-1131.

UNDESA (2007), *World Population Prospects: The 2006 Revision*, vol. ESA/P/WP.202, 61 pp., United Nations, Department of Economic and Social Affairs, Population Division (UN-DESDA); United Nations;, New York.

UNEP (2005), *Ecosystems and Human Well-being: Scenarios*, Millennium Ecosystem Assessment, vol. 2, 561 pp., United Nations Environment Programme (UNEP); World Health Organization (WHO); Island Press, Washington, Covelo, London.

UNEP (2006), *Challenges to International Waters – Regional Assessments in a Global Perspective*, 120 pp., United Nations Environment Programme (UNEP), Nairobi, Kenya.

UNEP (2007), *Global Environment Outlook: Environment for Development, GEO 4*, 576 pp., United Nations Environment Programme (UNEP), Nairobi, London.

UN-Water and UNESCO (2009), *Water in a Changing World*, 432 pp., World Water Assessment Programme, United Nations Educational, Scientific and Cultural Organization (UNESCO) Pub., Earthscan, Paris; London.

Valkering, P., R. van der Brugge, A. Offermans, and N. Rijkens-Klomp (2010), Scenario analysis of perspective change to support climate adaptation: lessons from a pilot study on Dutch river management, *Reg. Environ. Change*, 1-13, doi: 10.1007/s10113-010-0146-0.

van der Heijden, K., R. Bradfield, G. Burt, G. Caims, and G. Wright (2002), *The Sixth Sense - Accelerating Organizational Learning with Scenarios*, 320 pp., John Wiley & Sons, Ltd., West Sussex, UK.

van Notten, P. W. F., J. Rotmans, M. B. A. van Asselt, and D. S. Rothman (2003), An updated scenario typology, *Futures, 35*(5), 423-443, doi: 10.1016/S0016-3287(02)00090-3.

van Notten, P. W. F., A. M. Sleegers, and M. B. A. van Asselt (2005), The future shocks: On discontinuity and scenario development, *Technol. Forecast. Soc. Change., 72*(2), 175-194, doi: 10.1016/j.techfore.2003.12.003.

van Vliet, M., K. Kok, and T. Veldkamp (2010), Linking stakeholders and modellers in scenario studies: The use of Fuzzy Cognitive Maps as a communication and learning tool, *Futures, 42*(1), 1-14, doi: 10.1016/j.futures.2009.08.005.

Varis, O., A. K. Biswas, C. Tortajada, and J. Lundqvist (2006), Megacities and water management, *Water Res. Dev., 22*(2), 377-394, doi: 10.1080/07900620600684550.

Varum, C. A., and C. Melo (2010), Directions in scenario planning literature – A review of the past decades, *Futures, 42*(4), 355-369, doi: 10.1016/j.futures.2009.11.021.

von der Gracht, H. A., and I. Darkow (2010), Scenarios for the logistics services industry: A Delphi-based analysis for 2025, *Int. J. Prod. Econ., 127*(1), 46-59, doi: 10.1016/j.ijpe.2010.04.013.

Wack, P. (1985), Scenarios: uncharted waters ahead, *Harv. Bus. Rev., 63*(5), 73-89, doi: 10.1225/85516.

WBCSD (2006), *Business in the World of Water WBCSD Water Scenarios to 2025*, 48 pp., World Business Council for Sustainable Development (WBCSD), Conches-Geneva.

WHO and UNICEF (2008), *Progress on Drinking Water and Sanitation Special Focus on Sanitation*, 58 pp., Joint Water Supply and Sanitation Monitoring Programme of the United Nations Children's Fund (UNICEF) and the World Health Organization (WHO), New York; Geneva.

World Water Council (2000), *World Water Vision: Making Water Everybody's Business*, 128 pp., Earthscan Publications Ltd., London.

Wright, G., K. van der Heijden, G. Burt, R. Bradfield, and G. Cairns (2008), Scenario planning interventions in organizations: An analysis of the causes of success and failure, *Futures, 40*(3), 218-236, doi: 10.1016/j.futures.2007.08.019.

8 Concluding Remarks

Concluding Remarks

Scenario planning offers a broad range of possibilities to deal with uncertainties caused by changing framework conditions such as demographic change. There are even so many possibilities that the research community attests, that scenario planning contains a high degree of "methodological chaos." This dissertation contributes to shedding some light into this chaotic darkness. The introductory research stream gave a first overview on the possibilities in the sanitation sector and in the context of integrated water resources management. The two possible scenario goals were analyzed in a separate research stream each.

The predictive research stream has analyzed the impacts of demographic change on wastewater fees and has compared them with other effects. I could show that, if a short time horizon and a focus on a few well known trends is given, uncertainty can be handled by the use of a ceteris paribus analysis and a sensitivity analysis.

In the explorative research stream the possibilities of scenario planning to identify possible future challenges was assessed. In a systematic research review possible design options of a combination of scenario planning and the Delphi technique were derived. Journal article E2 demonstrated that objectivity and creativity can be enhanced by a combination of the two methods. In journal article E3 I undertook a Delphi-based scenario study based on the findings of journal article E2. The goal was to identify possible future challenges for the sanitation sector in the year 2050. The integration of expert interviews and the assurance of anonymity were especially fruitful with regard to the identification of weak signals. The use of Fuzzy Cognitive Maps facilitated the integration of expert knowledge and the illustration of driver interdependencies. The results of the explorative research stream offer an excellent starting point for decision-makers in the sanitation sector to incorporate possible states of the future in their long range planning activities. Since a high effort is required to realize a complete scenario planning study, I recommend conducting a scenario exercise within a broader framework, such as an association or other larger organizations. Nevertheless, even small and medium sized sanitation organizations should be encouraged by this dissertation to incorporate scenario thinking in their daily routine.

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