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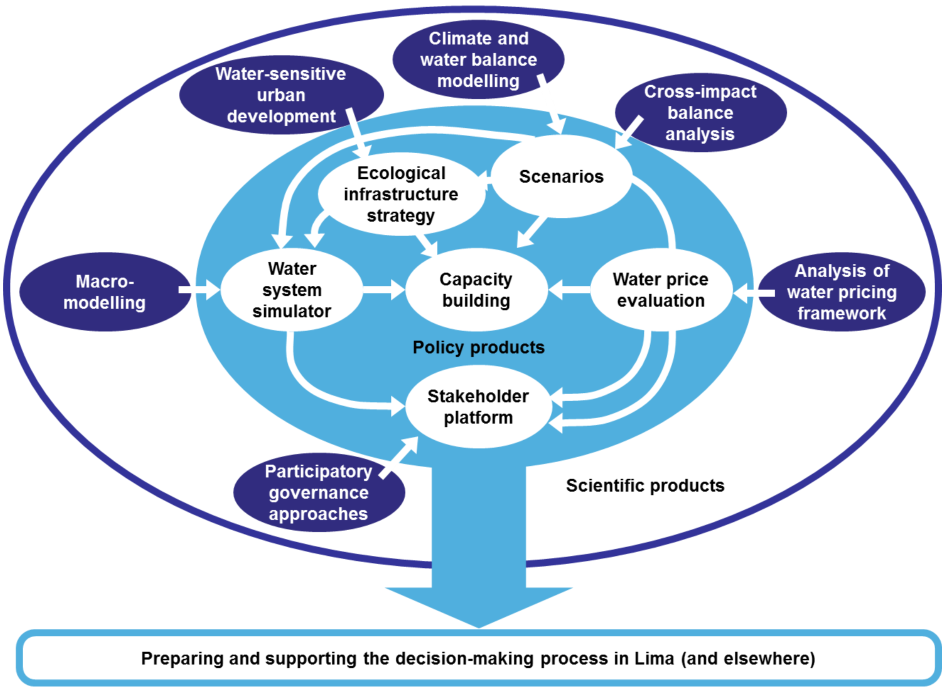
LiWa

Sustainable Water and Wastewater Management in Urban Growth Centres Coping with Climate Change - Concepts for Lima Metropolitana (Perú) - (LiWa)

Transferability Manual
How can LiWa be applied to other regions of the world?



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Whilst great care has been taken in the compilation of this document, the responsibility of the work package descriptions rests with the work package leaders.

This report will also be made available on the webpage www.lima-water.de

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0 Preface

By Dr Andrea Koch-Kraft, DLR (Project Management Agency of BMBF)

With global urbanisation still progressing fast, solutions for sustainable urban development paths are in high demand. Whilst many technologies are claimed to be available and to provide solutions to the challenges of practice, their successful implementation lacks behind in many cases. Filling the knowledge gap is one of the main tasks of scientific research. Furthermore, it needs to be assessed which solutions are the most appropriate ones fitting the local conditions.

During the last decade, a major research activity on the sustainable development of the megacities of tomorrow became the pace-setter in cooperation projects focusing on energy- and climate-efficient structures in urban growth centers. The “FUTURE MEGACITIES” programme – funded by the German Federal Ministry of Education and Research (BMBF) – set out to shift research agendas from “research about cities” to “research for cities”. The LiWa-project worked as one of nine bilateral research teams on immediate urban issues which require short and longer-term solutions. All research teams had to follow a set of innovative research principles which included the following:

- Be solution-oriented and thus aim at the needs of the people affected.
- Offer a system solution: include the interaction of social, economic and ecological transformations.
- Be transdisciplinary: include all scientific disciplines needed and include practitioners and stakeholders.
- Be implementation oriented and demand-driven.
- Be user-oriented: take a participatory approach, develop your project in close co-operation with decision makers and stakeholders, involve civil society and consider gender issues.
- Generate sound scientific data and scientific methods and develop good practice examples for the benefit of the project-city and beyond.
- Consider the impact of the project after the funding has come to an end.

This manual illustrates how a recombination of scientific disciplines and the incorporation of stakeholder-, practitioner- and civil society-knowledge can lead to much needed social and institutional innovations in Lima and beyond. The processes and steps for the implementation of measures described in this manual were developed by the LiWa project to be adapted in many more cities. What it needs are urban pioneers open to new approaches and to new alliances for an ultimate goal: a livable city for all.

Dr Andrea Koch-Kraft
PT-DLR, Project Management Agency – part of the German Aerospace Center - Environment, Culture, Sustainability

The Project Management Agency ensures that the research projects are in compliance with the goals and principles of the research programme.

1 Executive Summary

1.1 Introduction

The first chapter of this manual presents a very brief overview of the LiWa project (”Sustainable Water and Wastewater Management in Urban Growth Centres – Coping with Climate Change – Concepts for Lima Metropolitana (Peru)”), which was funded by the German Ministry of Education and Research (BMBF). The project started with a preparatory phase (2005 – 2008), continued with a main phase (2008 – 2013), and finished with an additional phase (2013 – 2014).

Within the project, a set of methods and tools were developed and applied to the question of how the city of Lima can prepare for the future challenges posed by climate change and population development focussing on water and sanitation. Whilst methods and tools were developed with the situation of the desert megacity Lima in mind, they are universal and can be applied also to other urban regions elsewhere in the world.

The manual provides comments and recommendations on how to adapt and apply the methods to other places. The driving question behind compiling the manual was “What should the Mayor or the city planner of the city of XXX know when he/she wants to apply the LiWa methods and tools to his/her city?”.

This manual assists in tackling the challenges of the future. This manual was compiled and edited by ifak e. V. Magdeburg (General Coordinator of the LiWa project), with input from the project partners, which are gratefully acknowledged. The coordinator and all partners are happy to provide further information and assistance when required.

1.2 Additional information about the LiWa project

For a concise overview of the LiWa project, the following sources are recommended:

- Project webpage: www.lima-water.de, with information and downloadable documents in English, Spanish and German languages.
- Set of flyers in English and in Spanish languages, updated 2014 – available from the coordinator and from the project webpage
- Video films:
  - 2 videos produced by the LiWa project, 1 video produced by Deutsche Welle DW German TV International: see http://www.lima-water.de/en/film.html?Menu=11. These videos are also available in Spanish and in German (on the same webpage)
  - 1 video produced by the “Future Megacities” programme of BMBF: see http://future-megacities.org/index.php?id=video
- Webpage www.future-megacities.org (which also includes the results of all projects of the “Future megacities” programme of BMBF
- Overview papers, providing a summary of the entire LiWa project:
  - In Spanish:
    Schütze, M., León. C. (2013): Gestión del agua y aguas residuales en megaciudades - ¿Cómo puede una ciudad prepararse para el futuro? Un proyecto en Lima / Perú; Revista Ambiental. Colegio de Ingenieros del Perú, 8, 2013, 6-11

- In English:
  Hayward, K.; Schütze, M. (2014): Lima 2040: water management for a future desert megacity - Interview with Manfred Schütze; water 21 – Magazine of the International Water Association (IWA); August 2014; 39-43
  Schütze, M. (2012): Water and Wastewater Management in Megacities – How can a city prepare itself for the future? A project in Lima/Peru. gwf Wasser/Abwasser, S1/2012, 64-68
- In German:
  Max, A.; León, C. (2013): LiWa – Ein Interview mit Christian D. León zur Situation der Wasserversorgung der peruanischen Wüstenstadt Lima. Columbus, Geographisches Institut der Universität Heidelberg; 04-2013, Seiten 7 - 11

References about the individual, more detailed, aspects of the project are given in the subsequent sections.

1.3 A brief summary of the LiWa project – Results of LiWa

This chapter provides a short summary of the entire LiWa project. This assists the reader in understanding the subsequent sections which provide detailed insights into the manifold working areas and results of the LiWa project. The LiWa project has developed an overall methodology and a number of tools and sub-methods. Figure 1 illustrates the underlying methodology and the various results of the LiWa project.

Using global climate models and the Intergovernmental Panel on Climate Change (IPCC) scenarios of climate change and downscaling these global models to the Peruvian river catchments, possible scenarios of **climate change impacts on water availability** for Lima can be derived. However, scenario building – driven by the question "How could the water system of Lima look like in the year 2040?" – is a far more complex task as it has to consider a variety of socioeconomic variables. Following a participatory approach, involving major stakeholders of the city, a set of scenarios for the future of Lima have been defined. Scenarios were used on the one hand as input for simulation of the water system and on the other hand as framework for formulation of the Action Plan.

This is addressed in more detail in the subsequent sections. **Scenario definitions** and **catchment modelling results** under climate change influences serve as input to modelling of the Lima water and wastewater systems.

A **water system simulator**, based on the fundamental principles of resource flux modelling and material flux analysis, was set up by ifak in close cooperation with the water company SEDAPAL, allowing to represent the water and wastewater systems of Lima in one single model. Water and wastewater flows, pollutant fluxes, but also energy production and consumption within the water system, are modelled. This allows to analyse various scenarios and acting options and their impacts on the entire water system. In a similar way, the simulator can be applied in any city. Hence, modelling and scenario building assist informed discussions and thus supports towards **participatory decision-making processes**, resulting in decisions borne and supported by the various stakeholders. This process resulted in the **Action Plan "Lima 2040"** which was set up jointly and signed by highly ranked representatives of the key institutions in Lima (SEDAPAL water company, National Water Authority, Metropolitan Government of Lima, NGO sector).

An analysis of the tariff structure and the development of **new tariff structures**, in close cooperation with the regulatory agency SUNASS, complements the project. Integration of tariffs in the water system simulator allows the effects of tariff systems to be evaluated for the entire system. A **capacity building** component of the project ensures that the project's findings will be transferred to engineering practice. Capacity building included the development of modules for academic courses, practical training in international summer schools, but also comprised of several professional development courses. Furthermore, an **eLearning platform ("LiWa Academy")** was set up and was also used in the professional development courses held in Lima. Furthermore, concepts of water sensitive urban design were adapted to the desert megacity of Lima, resulting in the **Lima Ecological Infrastructure Strategy**. As a pilot implementation of this concept, a **Wastewater treatment park – "Parque de l@s niñ@s"** was constructed and inaugurated in the Chuquitanta area of Lima's San Martín de Porres district in August 2014.

Figure 1 provides an overview of the overall methodology of LiWa, whilst Figure 2 illustrates the various sub-products of the project. Two types of products can be distinguished:

- Policy products refer to project results, measures and tools which are of direct use for decision makers in Lima. They aim at improving the decision-making processes in Lima's water sector. For this purpose, they are meant to safeguard that existing and new scientific knowledge on Lima's water sector is actually applied when it comes to practical decision-making.
- Scientific products refer to scientific innovations and insights derived in this project. They are of relevance beyond the scope of Lima and of immediate use for the worldwide scientific community. Nevertheless, they are also an essential precondition for the derivation of the policy products. They generate new knowledge which is needed for decision-making in Lima (and elsewhere).

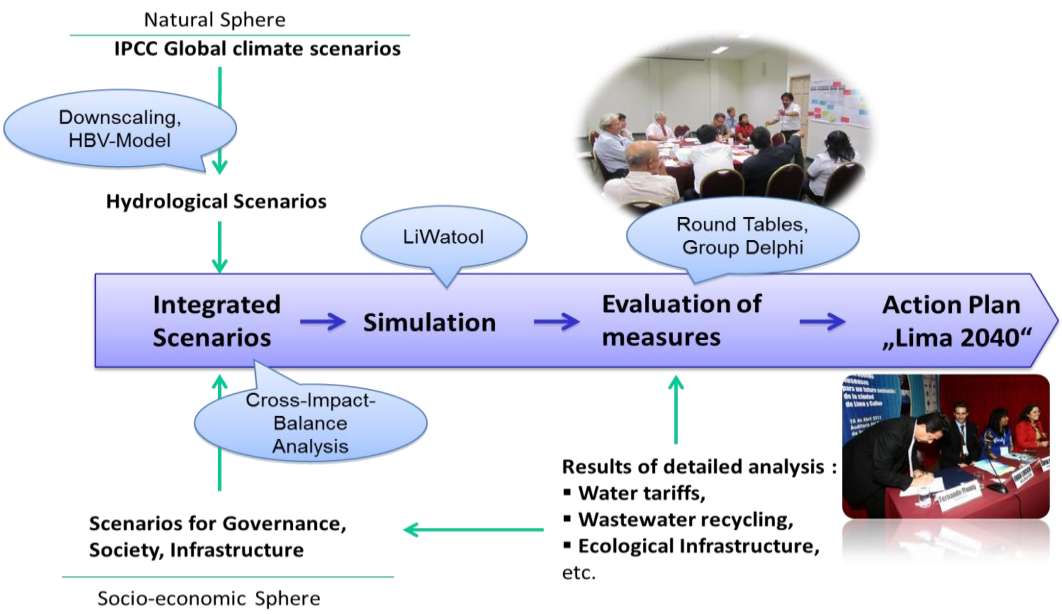


Figure 1: Summary of the LiWa project methodology (Source: ZIRIUS)

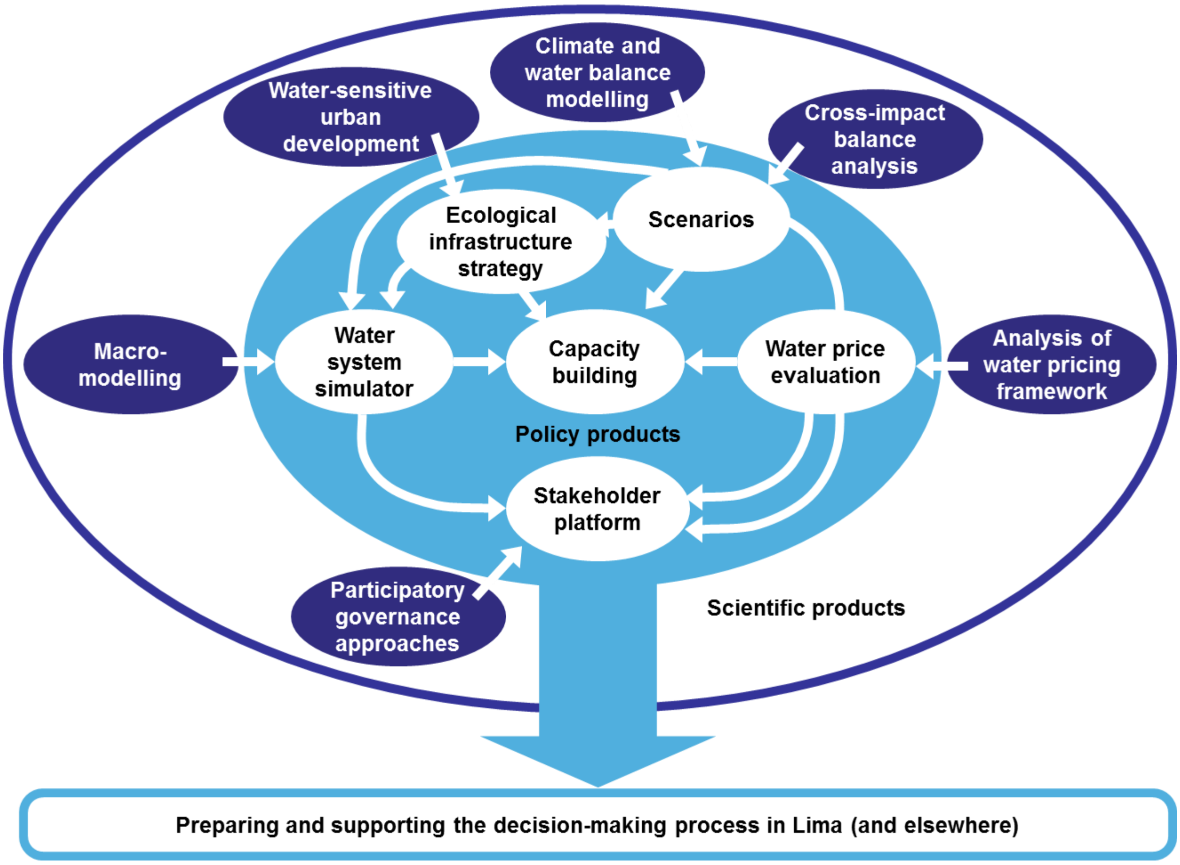


Figure 2: Overview of the LiWa project products.

In a nutshell, the project has various outcomes with worldwide application potential:

- Methodology/programs for downscaling of IPCC models to local context
- Simulator, transferable to other contexts and sectors
- Methodology for participative building of consistent scenarios
- Participatory method: Combination of scientific analysis and multi-stakeholder dialogue to agree on an Action Plan
- Concept of Water Sensitive Urban Design for open space planning, guidelines, planning tool
- E-Learning system, course modules
- Studies and suggestions regarding how to build good water tariff systems
- Lima Ecological Infrastructure Strategy

2 Recommendation for the transfer of LiWa methodologies to other cities

2.1 Overall methodology of LiWa

The overall, inter- and transdisciplinary, methodology of the LiWa project has been summarised in Section 1.3 and, in particular, in Figure 1. The subsequent section provides specific results of the individual aspects covered by the overall methodology.

2.2 Specific results

Input to this section provided by Dr Jochen Seidel, IWS, University of Stuttgart

2.2.1 Collection of hydrologic data

For downscaling purposes, meteorological data were collected including temperature and precipitation time series. This step is necessary in order to have information at a basin scale, were both Global Circulation Models (GCM) outputs and the collected data are analysed.

Furthermore, data from global data sets (GPCC, Delaware, CRU) were gathered and compiled for the study area. These data were analysed and compared with local data to assess their quality. This step is important especially when not enough information is available for modelling purposes. The variables considered here were temperature and precipitation.

To address the impact on hydropower production, data on the hydropower plants along the Rimac River and its tributaries were gathered and processed. These include the maximum capacity of the reservoirs, evolution of the volume in the reservoirs at a function of time (monthly scale), the maximum discharge, the installed power as well as monthly discharge information (30 year average 1966-1995).

For hydrological modeling purposes, *in situ* discharge data in the study area (rivers) were also collected. This is essential for calibrating and validating the models used in the analysis.

2.2.2 Selection of climate change scenarios

For climate modelling, two scenario families from the IPCC Special Report Emissions Scenarios were chosen:

- A2 describes a very heterogeneous world with high population growth, slow economic development and slow technological change.
- B2 describes a world with intermediate population and economic growth, emphasising local solutions to economic, social, and environmental sustainability.

These scenarios are moderate and therefore represent a middle situation from the possible ranges.

2.2.3 Climate and water balance modelling

Interpolation of data: Before getting into hydrological modelling, meteorological data were analysed, completed, gap-filled (missing data) and interpolated on a daily basis temporal resolution using External Drift Kriging (EDK). The useful time span of the meteorological information was constrained by the availability of discharge data, which was available from 1999 to 2008. This was not an imposition but rather a restriction from the data collection step (availability of information). The useful time span of the meteorological information was constrained by the availability of discharge data. In this way, information from 1998 to 2008 was considered in this step. The number of stations varied from basin to basin. The main basin Rimac contributed with 12 stations, while Chillon and Lurin with 6 and 5 respectively.

After the interpolation step, daily, monthly and yearly precipitation maps were generated. Figure 3 shows an example of an average monthly precipitation map in the basin Chillon.

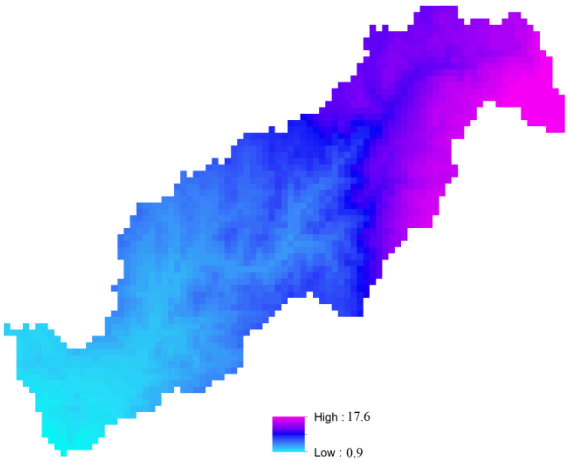


Figure 3: Average Precipitation map (mm) in the basin Chillon basin for the month of March (1999-2008)

Water balance in different Rimac sub catchments: The sub catchments in the study are were derived from a digital elevation model (DEM) for the points (gauging stations) where discharge data was available. Subsequently, the water balance was performed by estimating the potential evapotranspiration and considering the continuity equation in each lake. Relevant additional information for this purpose was also incorporated. This was regarded as a first approximation for the water availability estimation in the defined points. The same analysis was done in the regions on the Pacific side of the Andes, where the water is diverted to Lima via channels and tunnels (Marca I-V projects).

Rainfall-runoff modelling: With the previous information and estimations, two different hydrological models (HBV, Hymod) were calibrated and validated in order to have a tool for future discharge estimates. An important consideration here is the different time scales involved. While temperature and precipitation time series have a daily resolution, discharge data and lakes volume variations had a monthly temporal resolution. This meant that the calibration procedure had to be treated differently for taking into account this scales mismatch. Important additional information can also be considered in rainfall-runoff modelling, as for example land use.

Downscaling of precipitation and temperature: For assessing the expected behaviour of precipitation and temperature for the future, the GCM output cannot be used directly for hydrological climate change impact studies. Therefore, a statistical downscaling approach (quantile-quantile transformation) was used to transform the CGM output (precipitation, temperature) to the local scale. The final result in this step was the estimation of the discharge in the next four decades. Based on past observations, the expected discharge variation according to each scenario was then estimated, and this constituted the main result of the study. As an example, Figure 4 shows the monthly average discharge in Santa Eulalia sub catchment and the result of the future discharge estimation for each scenario

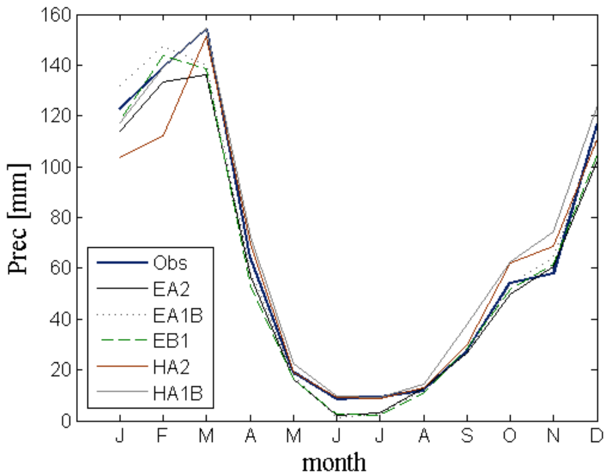


Figure 4: Monthly average discharge for observations (obs) and analysed scenarios in Santa Eulalia sub-catchment

2.2.4 Particular successes

The main purpose of the study was to have an estimation of the main hydro-climatological variables for the next decades. This was fulfilled and different scenarios for the different estimated climate conditions were introduced. As a part of the transfer of information/results in the project, the adapted and calibrated hydrological models were transferred to various partner institutions in Lima for their further use. Workshops were carried out in this process for the details.

2.2.5 Recommendations for adaptation/application in another city

Basically, the method used for climate and water balance modelling and climate change conditions in the LiWa project can be applied to any region or study area. However, specific adjustments and considerations have to be made, depending on the given circumstances. The most crucial point regarding this is the data availability and data quality for interpolation and model calibration purposes. Parameters of particular importance include precipitation, temperature, evapotranspiration and discharge information. In the case of the LiWa project, the data transfer of information from the Peruvian authorities took time and, additionally, most of the data records did not cover long periods and/or exhibited data gaps. Hence the missing data had to be filled. In this regard, a complete and well documented data set for a specific study area would significantly reduce the amount of work to prepare the data for further processing and reduce the uncertainty in the modelling steps. This problem can be overcome to a certain degree when resorting to remote sensing and other freely available data sets. Other data sets (e.g. climate model runs, gridded precipitation data sets, digital elevations models) are freely available globally and therefore suitable to use for any region in the world.

An important issue in the case of the LiWa study area was the pronounced topography and climatic conditions, which lead to a very high temporal and spatial variability of the hydro-climatic variables. This should be considered in other regions (cities) due to the extra challenges it poses to the quality and analysis of the data. Furthermore, the complexity of the hydrological processes represented by the models has to be adapted to the local conditions when applying this method to other regions.

2.2.6 Additional information

Further reading:

- Chamorro, A. (2014): Stochastic and Hydrological Modeling for Climate Change Forecasting, PhD thesis, Institute for Modelling Hydraulic and Environmental Systems (IWS), University of Stuttgart.

Contact:

- Dr Jochen Seidel, IWS, University of Stuttgart, jochen.seidel@iws.uni-stuttgart.de

2.3 Specific results – scenario planning for sustainable water management

Input to this section provided by Dipl.-Ing. Christian León, ZIRIUS, University of Stuttgart

2.3.1 Why scenarios?

Future is uncertain and with regard to many fields not predictable. Despite this uncertainty, decisions have to be taken today with regard to investment plans and long term strategies. To develop robust plans and strategies for decision-making that consider future risks and potentials, scenarios have proven to be a useful tool. In the LiWa project, scenarios are used as a means to assess and identify strategic options towards sustainable water management. Using scenarios helps to estimate risks and potentials of different measures and activities *before* they are implemented. Scenarios describe different possible developments in the future. They give an approximation of what the future might hold, they do not pretend to become true, though are not trend extrapolations or forecasts. One definition of scenarios is:

Scenarios are "...an internally consistent view of what the future might turn out to be - not a *forecast, but one possible future outcome"*
(M. Porter, 1985: Competitive Advantage. Free Press, New York).

By defining the influence of different factors on future water management and by analysing their interrelationships, future scenarios can be constructed and the consequences of different options of measures and actions can be evaluated.

2.3.2 How to build scenarios

Scenario planning in the LiWa project has been conducted in a participatory way, involving the most relevant actors from different sectors and policy areas of the city (water company, public authorities, civil society and scientists). Participatory scenario building has the advantage to integrate different points of view, stimulate the discussion and exchange of perspectives and experiences between different actors. It helps to develop consistent trends for the future development by defining assumptions, driving forces and possible interventions.

Finally, participation helps to legitimize the scenarios and creates ownership for their future application.

There are different ways to build scenarios, although most of them usually follow the 6 steps described in the following table:

Table 1: Six steps in the scenario building process

1. Problem framing and definition of boundary conditions
2. Identification of driving forces (descriptors)
3. Formulation of possible developments of the descriptors (sub-scenarios)
4. Evaluation of descriptor interdependencies
5. Construction of consistent scenarios
6. Scenario transfer: Analysis of consequences and development of strategies

Each step is described in the following section, focusing on the experience of the LiWa project.

2.3.3 How to conduct a scenario building process

Before conducting a scenario study, a scenario team has to be established by nominating the participants. A core team, mainly scenario experts, should lead the process, and act as experts of the scenario methodology and as facilitators for the workshops.

As already mentioned in the section before, to integrate different viewpoints of people with different background knowledge, enriches the scenarios building process. This can be done by including them as part of the scenario team. This has the advantage that they get an inside view of the process and that it creates ownership. In case it is not possible to engage them through the whole process, experts can also be asked punctually when referring to specific topics. In the case of water management, these experts should not come solely from the water sector, but also come from other disciplines and backgrounds. The involvement of practitioners from the private sector and civil society enriches the process, improves communication and helps to create a common language between the participants. On the other hand, participatory processes usually are more time consuming. Finally, the decision depends on the available time budget for the process.

Guiding questions:

What are the available resources (regarding time, personnel and method expertise) for the scenario process? Is it possible to involve people from other sectors and disciplines throughout the whole process?

Step 1: Problem framing and definition of boundary conditions

The first step in the scenario building process is setting the systems boundaries regarding scope (e.g. water management) and specification of the issues that will be analysed (e.g. domestic, agricultural, or industrial use of water, or all of them). This first part of the definition is important to make explicit what aspects of the topic will and what aspects will not be considered. Defining the systems boundaries also refers to the definition of the a) spatial and b) temporal perspective of the scenario analysis. This means for the water topic, for example, to define the geographic limits of water management (local, regional, national; water catchment level) and to define the temporal horizon of the scenario analysis (e.g. 5, 10, 20 or more years into the future).

Guiding question:

What are the systems boundaries of the scenario field, regarding scope, spatial perspective and time horizon?

Step 2: Identification of driving forces (descriptors)
Driving forces or descriptors are the main factors that delineate the scenario field (here: water management). These can be, on the one hand, factors that describe the water management sector itself (e.g. water reserves, drinking water connections,…), and on the other hand factors located outside the water sector, but influencing the water sector, e.g. societal, technological, economic, ecologic, but also political and legal factors. Considering these kind of factors is crucial, as for many countries, water management in the future depends on many factors that are not mere technical ones.

As for a typical context analysis, there are many factors that have a different impact on the defined topic. Depending on the time available for the whole process and the level of detail that is desired, these factors can be clustered and then prioritized to focus on the most relevant factors only. The LiWa project has developed 13 descriptors sorted in 4 areas:

Table 2: 13 descriptors for water management in Lima

Governance	Government	Water company	Water tariffs	Water catchment management
Territory and population	Urban development	Population	Urban poverty	Water consumption
Water infrastructure	Water supply infrastructure	Water coverage	Water network losses	Wastewater treatment
Climate change	Water runoff in the rivers			

Guiding question:

What are the influencing factors (driving forces or descriptors) regarding the scenario field? Think of societal, technological, economic, ecologic, but also of political, institutional and legal factors. What factors have the major impact on the future development?

Step 3: Formulation of possible developments of the descriptors (sub-scenarios)
In this step, for each of the descriptors, several possible future developments have to be formulated, which in the following are referred to as different assumptions of each descriptor. For the formulation of future developments, it is useful to make first an analysis of the past trends and to conduct a literature review of future studies regarding each descriptor. Additionally or alternatively, experts can be asked about their conception towards future developments. These experts can be from the academic sector, but also be practitioners from enterprises, associations and public administration. In our experience, the latter tend to be more optimistic, expecting that political programmes will have a bigger and perhaps more positive impact on future developments. It is recommendable to include experts with different perspectives, optimists and pessimists, and not to run only a trend extrapolation or forecast. Commonly, for each descriptor, 2 to 3 alternative developments are defined. One example is shown in the following box:

Table 3: Example for alternative descriptor developments (sub-scenarios)

Descriptor	Sub-scenario 1	Sub-scenario 2	Sub-scenario 3
Population growth rate per year	Low (0.5%)	Medium (1%)	High (2%)

We recommend to elaborate for each descriptor an essay or fact sheet to document definitions, assumptions and developments.

Guiding question:

What possible developments can each descriptor show in the future? Think on realistic developments, continuing past trends, but also consider more extreme, positive and negative alternatives. When necessary, ask experts from different backgrounds.

Step 4: Evaluation of descriptor interdependence

Step 4 is the most laborious, complex and time-consuming step – the analysis of inter-dependences between the different descriptors/ scenario factors. If this step is done systematically, the time and effort that have to be invested depend directly on the *number* of descriptors and their variants. For the LiWa project, with 13 selected descriptors, 1132 cross-impact judgements for all variant pairs had to be given. Obviously, this analysis only could be realized due to sufficient time available during the project and due to the strong commitment of the participants. Some scenario builders use more intuitive, non-formalised methodologies to discuss descriptor interdependence as for example the "intuitive logics". All scenario methodologies, whether formalised or non-formalised, have the objective (and challenge) to select those bundles of descriptor developments that are consistent and arrange them into a set of scenarios, usually 3 to 5 scenarios. To ensure consistency, using formalised methods is more suitable. These scenarios can be validated and reproduced. One of these methodologies is the "Cross-Impact Balance Analysis" (CIB) (Weimer-Jehle, 2006), which has been used in the LiWa project and will be described in this section.

"Cross-Impact Balance Analysis" (CIB)

For the Cross-Impact Balance Analysis, the first step is to evaluate the interdependencies between each of the descriptor developments (sub-scenario). As this evaluation often depends on uncertain and partly subjective assumptions which need consolidation by a multilateral group assessment, it is recommended to involve experts and stakeholders at least during this step of the process. To involve different actors and perspectives can be done through a participatory process using different methodologies (workshop or group Delphi). The objective is to assess the inter-relations, how each descriptor influences other descriptors and in turn, by which other descriptors it is being influenced. This process should be moderated to assist the participants to obtain a common view about the interrelations. For the assessment of the interrelations we use a scale from -3 to +3:

- -3: strong inhibiting influence
- -2: inhibiting influence
- -1: slightly inhibiting influence
- 0: no influence
- +1: slightly promoting influence
- +2: promoting influence
- +3: strong promoting influence

Because each descriptor sub-scenario can have more than one influence (direct or indirect) to another descriptor`s sub-scenario, it is recommended to specify these interrelationships using the above mentioned scale within a matrix.

Table 4: Example of a matrix for cross-impact balance analysis

		Government		Water Company			Water tariffs	
		A1	**A2**	**B1**	**B2**	**B3**	**C1**	**C2**
Government	**A1**			0	2	-2	-3	3
	A2			1	-3	2	3	-3
Water Company	**B1**	0	0				-3	3
	B2	0	0				-3	3
	B3	0	0				0	0
Water tariffs	**C1**	0	0	0	0	0	0	0
	C2	0	0	0	0	0	0	0

More details about the methodology can be read in the guideline “Introduction to qualitative systems and scenario analysis using cross-impact balance analysis” (download: http://www.cross-impact.de/english/CIB_e_MBl.htm).

Step 5: Construction of consistent scenarios

Once all interdependencies have been formulated within the CIB matrix, a useful tool that helps to calculate the consistent scenarios, is the software “ScenarioWizard”. This software can be downloaded for free from the CIB method website: http://www.cross-impact.de/english/CIB_e_ScW.htm

Usually, the results of the ScenarioWizard tool provides a range of scenarios that have to be analysed, undergo interpretation and selected to get a manageable number of scenarios. These scenarios have to be clearly different, plausible and useful for the next step of scenario transfer, where they serve for the development of strategies. The final scenarios can include:

1) a descriptive title for each scenario,
2) a table showing the development of each descriptor in each scenario,
3) a narrative story of each scenario (storylines),
4) Illustrations,
5) Quantitative information, if available, e.g. through scenario simulation.

An example from the LiWa project can be found in the following document:

- Kosow, H.; León, C.; Schütze, M. (2013): Escenarios para el futuro – Lima y Callao 2040. Escenarios CIB, storylines &simulaciónLiWatool. ProyectoLiWa, http://lima-water.de/documents/scenariobrochure.pdf (in Spanish)

Step 6: Scenario transfer: Analysis of consequences and development of strategies

Scenarios give a brought view about the future, where uncertainty is high and associated with complexity. Scenarios can be used as stand-alone result for communication to the general public. As a useful tool to (re)consider measures and plan more robust and effective strategies, scenarios can also provide valuable information for decision-makers. As all scenarios are possible to occur, even the more catastrophic or utopic ones, different measures can be evaluated relating to their viability and effectiveness if one of these scenarios happens.

When numerical scenarios are required and if a suitable numerical model is available, then the qualitative scenarios can be quantified and used as input parameter sets for simulation runs to evaluate effects of the scenarios on future system behaviour, strategies and measures. Thus, measures can be modified or arranged to strategies that are more robust against future risks and threats.

The robustness and effectiveness of each measure can be evaluated using a simple table:

	Scenario A	*Scenario B*	*Scenario C*	*…*
Measure 1				
Measure 2				
Measure 3				
…				

Scenarios themselves may also include some strategic elements and/or give some hints if measures can be implemented depending on the boundary conditions (resources, capabilities, actors, etc.). Existing strategies or planned measures then can be evaluated if they a probable to be implemented in the different scenarios.

Guiding question:

Assuming scenario A (B, C,…) would occur in the year X, which measures can be implemented and would be effective? What are the opportunities, threats and risks when implementing different measures? How can they be designed to become more robust (i.e. effective in many scenarios)?

References:

- Kosow, H., León, C. (2014): Die Szenariotechnik als Methode der Experten- und Stakeholdereinbindung. In: Niederberger, M.; Wassermann, S. (Hrsg.): Methoden der Experten- und Stakeholdereinbindung in der sozialwissenschaftlichen Forschung. Springer VS.
- Weimer-Jehle W. (2006): Cross-Impact Balances - A System-Theoretical Approach to Cross-Impact Analysis. Technological Forecasting and Social Change, 73:4, 334-361

2.4 Specific results –the hybrid scenario methodology of the LiWa project (CIB & LiWatool simulation)

Input to this section provided by Dipl.-Soz.Wiss. Hannah Kosow, ZIRIUS, University of Stuttgart

2.4.1 What has been done?

In the LiWa project, the construction of integrated scenarios on future water supply of Lima (‘Lima’s water futures 2040’) has been supported by a newly developed ‘hybrid’ (or qualitative-quantitative) scenario methodology, combining qualitative scenarios (constructed with the cross-impact balance analysis (CIB, see Section 2.3) with the LiWatool simulator (Section 2.5).

The methodology belongs to the family of so-called “Story and Simulation approaches” (cf. Alcamo, 2008), and more specifically was based on the concept of “context scenarios” (cf. e.g. Weimer-Jehle *et al.* 2013).

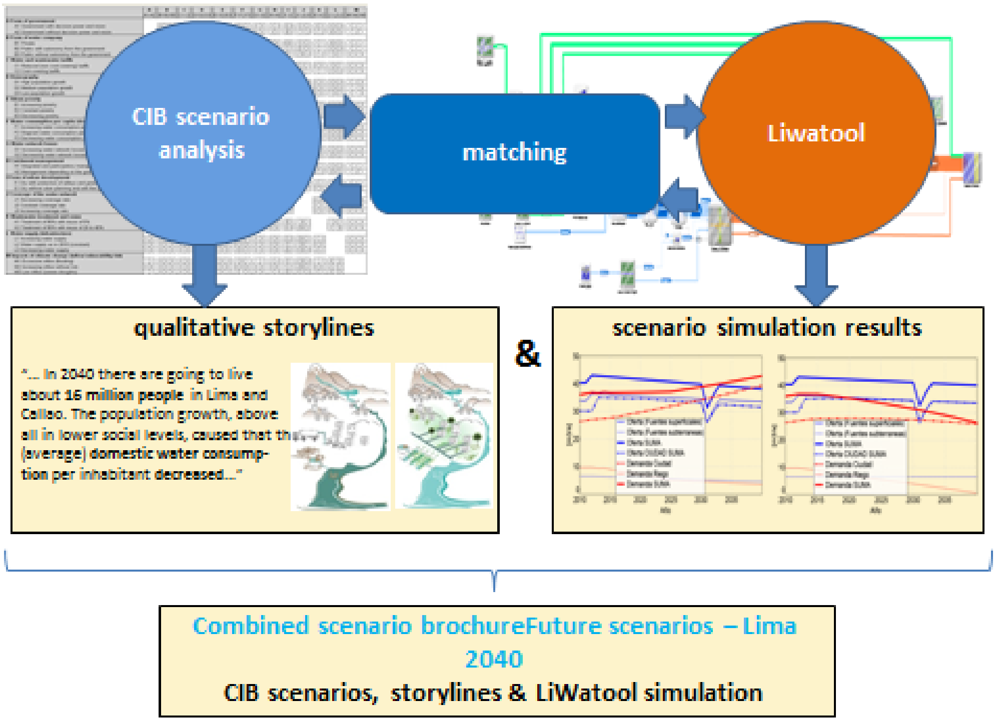
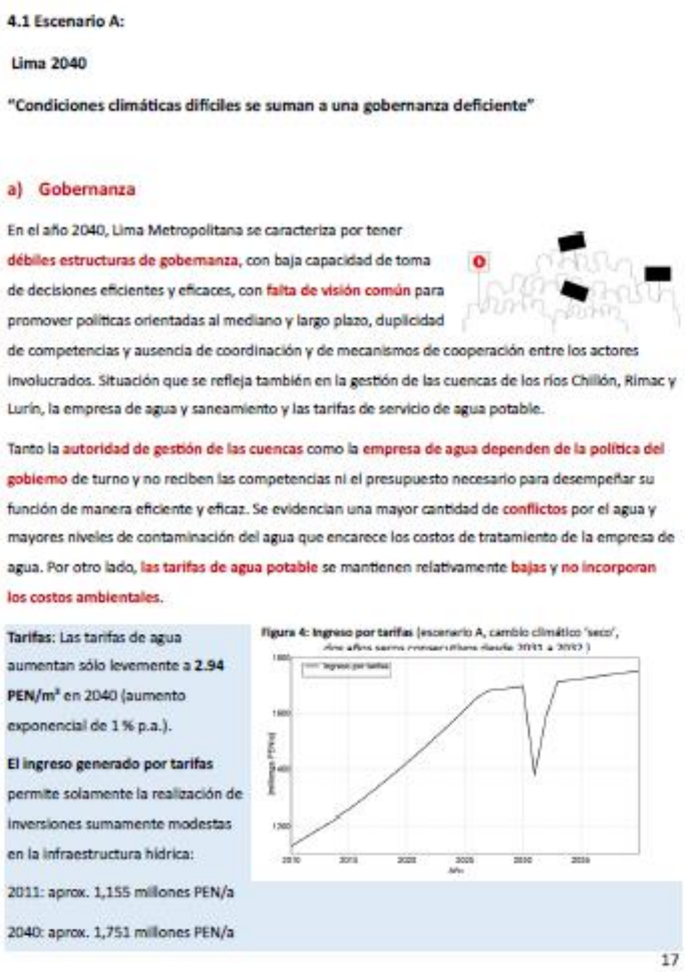


Figure 5: The hybrid scenario methodology of the LiWa project combining CIB and LiWatool (source: own representation)

In form of a pioneer application, a close combination of CIB with LiWatool was realized with CIB providing LiWatool with qualitative context scenarios serving to define numerical input parameter sets for simulation. The CIB scenarios were on the one hand elaborated into qualitative storylines, describing the alternative water futures of the city of Lima in text form. On the other hand, 10 out of the 13 scenario factors of the CIB scenarios (see Section 2.3) were translated into numerical indicators and time series through a matching process, to provide the simulations with input parameter *sets* corresponding to the LiWa scenarios. Therefore, information on past, present and possible future developments was discussed for each scenario factor. After a first simulation, the qualitative scenarios were reconsidered (iteration), and the simulation was repeated.

Finally, a combined scenario 'product' was realized in form of a brochure (Kosow *et al.*, 2013; see Section 2.4.4 for reference details), where the broader verbal descriptions of the four alternative scenario families (e.g. containing information on possible future governance structures) were underpinned with more specific numerical information with regard to technical, environmental and socio-economic aspects a) for simulation input and b) adding simulation results as e.g. the future water balances, the future income by tariffs and others to each scenario.


4.1 Escenario A:

Lima 2040

"Condiciones climáticas difíciles se suman a una gobernanza deficiente"

a) Gobernanza

En el año 2040, Lima Metropolitana se caracteriza por tener débiles estructuras de gobernanza, con baja capacidad de toma de decisiones eficientes y eficaces, con falta de visión común para promover políticas orientadas al mediano y largo plazo, duplicidad de competencias y ausencia de coordinación y de mecanismos de cooperación entre los actores involucrados. Situación que se refleja también en la gestión de las cuencas de los ríos Chillón, Rimac y Lurín, la empresa de agua y saneamiento y las tarifas de servicio de agua potable.

Tanto la autoridad de gestión de las cuencas como la empresa de agua dependen de la política del gobierno de turno y no reciben las competencias ni el presupuesto necesario para desempeñar su función de manera eficiente y eficaz. Se evidencian una mayor cantidad de conflictos por el agua y mayores niveles de contaminación del agua que encarece los costos de tratamiento de la empresa de agua. Por otro lado, las tarifas de agua potable se mantienen relativamente bajas y no incorporan los costos ambientales.

Tarifas: Las tarifas de agua aumentan sólo levemente a 2.94 PEN/m³ en 2040 (aumento exponencial de 1 % p.a.).

El ingreso generado por tarifas permite solamente la realización de inversiones sumamente modestas en la infraestructura hidrica:

2011: aprox. 1,155 millones PEN/a

2040: aprox. 1,751 millones PEN/a

Figura 4: Ingreso por tarifas (escenario A, cambio climático 'seco',

17

Figure 6: Excerpt from the combined scenario brochure (Kosow *et al.*, 2013)

2.4.2 Particular successes

- This successful integration was realized in a joint effort between modelers from ifak, the scenario experts from ZIRIUS and the other German and Peruvian project partners
- Success factors were:
  - The openness and flexibility of the LiWatool simulator – which was newly constructed during the process.
  - The methodological interest into the pioneer application of the hybrid methodology and the willingness to invest considerable efforts into its realization and test.
  - The shared interest of all partners to learn (also from each other) during the process, especially in terms of inter- and transdisciplinary communication.
  - The readiness of all participants to leave their methodological 'comfort zone' and to open up to new and unusual approaches.
  - Availability of expertise for assessing the interdependences between social and model-related factors.

2.4.3 Recommendations for adaptation/application in another city

- Define numerical indicators and time series as early as possible, at best in parallel to the qualitative CIB scenario construction: to avoid mismatches between qualitative and quantitative definitions right from the beginning.
- If for developments, no information or data on possible future developments exists, be ready to invest into own research (internally or by consultants) to obtain sound estimations (going beyond ad-hoc expert judgments).
- Include the modelers into the scenario group that is constructing the qualitative scenarios a) to include the model’s perspective into the process right from the beginning and b) to develop a shared understanding by modelers, scenario experts, and local stakeholders.
- Define clear responsibilities, also for the matching i.e. translation of qualitative scenarios into quantitative input parameter sets: give the responsible one the necessary resources in terms of time, funding and power.
- Design the method integration as an activity/ work package of its own, including all project partners with some manpower, funding and time into this work package, as this hybrid approach is rather demanding in terms of time and resources.

2.4.4 Additional information

Further reading:

- Alcamo, J. (Ed., 2008): Environmental Futures. The Practice of Environmental Scenario Analysis. Elsevier.
- *With regard to the concept of “context scenarios” (in German, paper in English is forthcoming):* Weimer-Jehle W., Prehofer S., Vögele S. (2013): Kontextszenarien - Ein Konzept zur Behandlung von Kontextunsicherheit und Kontextkomplexität bei der Entwicklung von Energieszenarien [Context scenarios - a concept for addressing context uncertainty and context complexity in energy scenarios, in German]. TATuP 22(2), 27–36
- *The LiWa scenario brochure combining storylines and simulations (in Spanish):* Kosow H, Leon C, Schütze M (Eds.) (2013): Escenarios para el futuro - Lima y Callao 2040. Escenarios CIB, storylines & simulación LiWatool http://www.lima-water.de/documents/scenariobrochure.pdf

Contact

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  E-Mail: manfred.schuetze@ifak.eu
- Cross-impact balance analysis: ZIRIUS University of Stuttgart, Wolfgang Weimer-Jehle,
  E-Mail: Wolfgang. Weimer-Jehle@zirius.uni-stuttgart.de
  website http://www.cross-impact.de/index.htm

2.5 Specific results – macromodelling and micromodelling

Input to this section provided by Dr Manfred Schütze, ifak e. V. Magdeburg

2.5.1 Macromodelling

As a means to contribute to informed discussions and decisions, a macromodelling simulator was developed. The simulator allows to simulate, albeit in coarse form, the entire water and wastewater system, including the interactions between water supply, wastewater, irrigation and energy system (as far as related to the water system. The focus is on modelling the entire system, rather than on the individual components (such as individual pipes, for example) of the water system. For those, detailed simulators are available (“macromodelling”, see Section 2.5.2).

While the working title of the easy-to-use simulator is “LiWatool”, it can be applied to other regions of the world and also to other infrastructure systems. It was applied also during the discussions in a Round Table event and contributed significantly to better system understanding and to a positive discussion process. Implementation of the Lima water and wastewater system was done in close cooperation with the local partners, above all with the water and wastewater company SEDAPAL. Training courses were held with participants from a wide range of disciplines and institutions.

The simulator allows in particular:

- Simulation, analysis and visualisation of urban infrastructure systems (e.g. water, wastewater, waste, energy).
- Consideration of different scenarios, evaluation of potential action options.

- Modelling of flow, contaminant and resource fluxes.
- Demonstration and discussion of potential options with stakeholders and the general public.
- Awareness raising of processes and their effects in urban systems.
- Increased understanding of the system.
- Creating ownership of proposed solutions.
- Capacity building measures by hands-on experiments with the system.

- User-friendly and easy-to-apply model building and simulation.
- Flexible modification of modules and creation of the user’s own modules.
- Analysis of “what-if”-scenarios?
- Calculation and visualisation of complex and bi-directional interactions.

The simulator is characterised by the following properties:

- Graphical interface, allowing the user to build systems by drag-and-drop.
- Block library for water systems and information processing (extendible).
- Numerical solvers for linear and non-linear systems, including balancing between demand and supply sides.
- Features to define capacity and criteria functions (e.g. costs, consumption, environmental burden).
- Editor for user-defined models.

- Consideration of arbitrary (user-defined) fluxes.
- Various forms of output: Sankey diagrams, time-series, tables.
- Interface for import and export from/to text files and Excel.
- Scripting functionality for user-defined extensions.
- Interfaces with ifak's range of dynamic simulators for water systems.

The LiWatool simulator in its general form consists of a number of predefined modelling blocks (e.g. rivers, groundwater wells, drinking water plants, water distribution network, city (districts), wastewater treatment plants, green areas, etc.), which allow the user to define his water system by connecting these blocks. This task is facilitated by a state-of-the-art graphical process flow scheme editor. For the links between the blocks, various pre-defined fluxes (e.g. river water, drinking water, wastewater), with different colour codes, are available. However, modelling blocks and fluxes can be modified and extended by the user according to the needs of the particular study (e.g. water quality constituents of importance to the study). Hence, the simulator is very flexible and adaptable. Whilst the general user-interface (drag and drop of blocks, connecting them by lines) resembles other simulation software (e.g. Matlab/ Simulink), it should be noted that LiWatool is a stand-alone software, not requiring any costly third-party software.

Figure 7 illustrates the main window of the simulator, depicting a simple educational modelling example, illustrating the task of drinking water distribution to two city districts.

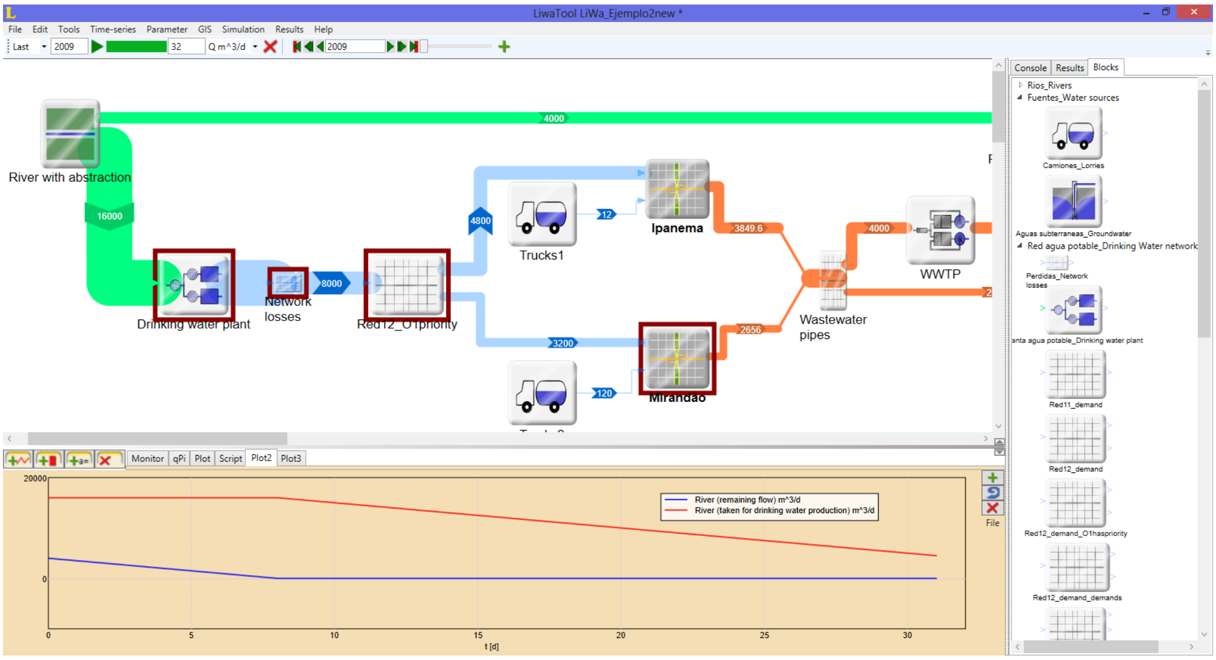

Figure 7: Main window of LiWatool simulator

Each modelling block (module) relates its inputs to its outputs, using user-definable parameters and variables. Also state variable information can be defined and used for bi-directional communication between the modelling blocks (see below). Time series information can be conveniently integrated by import and export features from/to Excel spreadsheets. Additional features for model building include unlimited nesting of submodels, thus enhancing the visualisation of system models. Evaluation criteria can be defined in a flexible way by means of capacity functions, and by static and dynamic evaluation functions, considering user-definable groups of cost categories. The algebraic and discrete equation system defined by the user by setting up the model in the graphical editor is solved by a set of various numeric solvers. Simulation output is represented in a number of different ways: Besides user-configurable time-series charts, numerical output and Excel export features, Sankey diagrams, which are generated automatically from the simulation results and which illustrate the fluxes within the system for various time steps, represent a powerful means of visualisation. These diagrams, with line width being proportional to the flux value represented, have proven to be very useful in stakeholder meetings. All of these features are accessible to the user without any programming knowledge. In addition to this, more advanced users can define in a versatile way their own evaluation and plot routines making use of scripting interfaces.

For the specific application in Lima, various models of different spatial resolution have been set up. For the combined scenario-modelling approach (cf. Section 2.4), a coarse resolution (Lima and Callao as one single block) was chosen. This allowed to focus on the overall interaction within the system (e.g. drinking water supply, wastewater reuse, irrigation needs), without getting lost in the details of individual city districts. For planning tasks for individual city districts, a model with finer spatial discretisation can be set up (and has indeed been set up) using the LiWatool simulator.

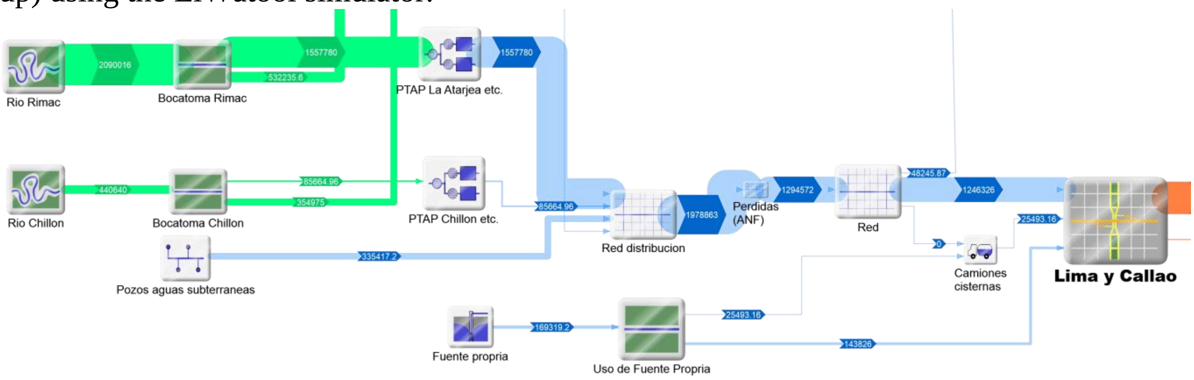

Figure 8: Extract of model setup for Lima (coarse spatial resolution)

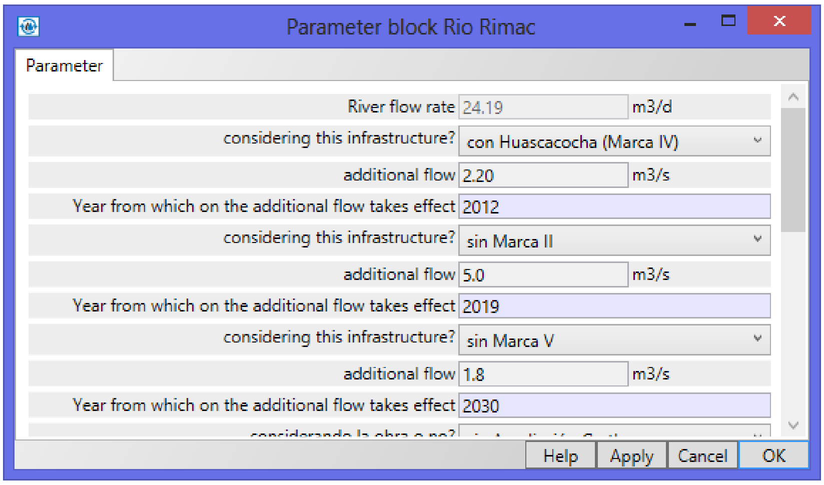

Figure 9: User-defined parameter dialogue for River Rimac block

Within the context of Lima, a number of different criteria were identified as being crucial for water management: Besides the obvious criterion water availability vs water demand, also revenue by water tariffs, energy consumption (within the drinking water and wastewater system), pollution (measured in terms of BOD discharges into the Pacific ocean) were defined. Furthermore, also the amount of green areas and water demand of irrigation play an important role, even more so as the Lima Ecological Infrastructure Strategy (adapting the concepts of water-sensitive urban design to arid zones) was proposed (see Section 2.8).

Four main scenarios were identified (see Section 2.3); various action measures for those were simulated using the LiWatool simulator. Figure 10 illustrates some results in an exemplary summarised way, providing a comparison of water availability and demand for the entire urban agglomeration, including its agricultural areas. It is obvious that, according to the pessimistic scenario “A” (which is shown here), demand will exceed availability rather soon. Details of the model setup for the Lima application and of the scenario simulations were summarised by Kosow *et al.* (2013).

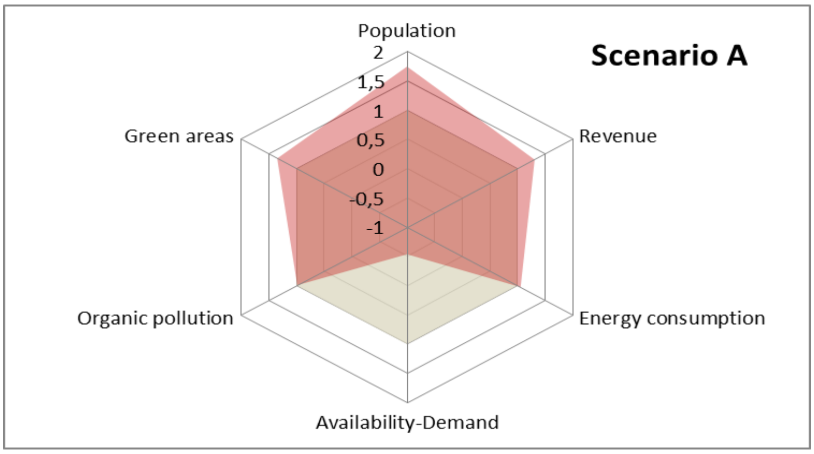

Figure 10: Summary of evaluation of Scenario “A” with regard to a number of different criteria in comparison with the base case (present-day situation)

This simulator, with the models of Lima implemented, played an important role in the derivation of the Action Plan “Lima 2040”.

2.5.2 Micromodelling

After overall strategic decisions were taken making use of the scenario methodology and the macromodelling tool developed, the next step in the planning process involved detailed planning. Here the suggested measures are analysed and planned in a far more detailed manner – for example, selection and setup of wastewater treatment technology etc. An important assistance to this step can be given by modelling tools, which here are denoted as “micromodelling tools”, in order to express that these are modelling some selected processes (not the city’s entire water system anymore) in far more detail.

Whilst a training course and an individual training workshop were held also on detailed dynamic modelling of wastewater treatment plants, such detailed modelling has not yet been uptaken by the partners in Peru. This is attributed to the fact that, by the time, the training course was held, the simulator for detailed dynamic modelling of those days did not meet fully the needs in terms of user-friendliness and ease-of-application as would have been required. However, recent simulator developments (cf. Alex *et al.*, 2013), resulting in easy-to-apply (and less cost-intensive) program might change this picture completely. Simulation can then take an important role, not only for planning, design and operation of water systems, but also for capacity building (a need for this was identified in the project, in particular on the operational level) and increasing system understanding.

2.5.3 Recommendations for adaptation/application in another city

The development within the LiWa project has resulted in a simulator which now can be readily applied also to other cities and infrastructure systems. LiWatool or derivates of it have already been applied to water systems of Astana/Kazakhstan, to Casablanca/Morocco and to sanitation modelling in Durban/South Africa and to examples in Central Europe (see reference list at the end of this section). The simulator allows program versions in other languages to be added easily. Test versions were set up in English, Spanish, German, French, Russian, and Bulgarian languages.

Experience from the project suggests that within the water company or water authority of the target city, a member of staff should be assigned to be responsible for the implementation and update of the model of the system represented in the simulator. Sufficient staff resources should be allocated, as this person will have to communicate with many different departments of the water company. As the simulator covers the entire water system, its application overarches the individual departments of water companies (e.g. drinking water network, sewer system, wastewater treatment etc.). Application of the simulator may, therefore, well also result in closer cooperation of the various individual departments of the water company and foster cooperation between water company and national bodies (e.g. river catchment authorities).

In general, for each (key) stakeholder, a key person should be assigned, who then should form part of a local steering group. This group then is also responsible for the quantification of the assumptions and time series. If necessary, data compilation should be assisted by an appropriate subcontract. In a similar way, this local steering group should have a crucial role in identifying evaluation criteria and in the compilation of potential action options.

The availability of a ready-to-use simulator, allowing the system to be visualised and discussed at an early stage of the project, assists considerably in the discussions between the project partners. Availability of an interface in the locally prevailing language ensures that not only the “elite” (those persons knowledgeable of English) can use the simulation tool and participate in the discussions.

2.5.4 Additional information

Further reading:

- Alex, J., Ogurek, M., Schütze, M. (2013): A novel simulation platform to test WWTP control options; 11th IWA Conference on Instrumentation, Control and Automation (ICA), 18-20 September 2013, Narbonne/France
- Kosow, H.; León, C.; Schütze, M. (2013): Escenarios para el futuro - Lima y Callao 2040. Escenarios CIB, storylines &simulaciónLiWatool. ProyectoLiWa, http://lima-water.de/documents/scenariobrochure.pdf (in Spanish)
- Ormandzhieva, Z., Schütze, M., Alex, J. (2014): Modelling and simulation of new sanitation concepts; 13th International Conference on Urban Drainage, Surawak, Malaysia, 7-12 September 2014

- Robleto, G., Schütze, M., León. C., Rodriguez, I., Alex, J. (2011): Sustainable Planning and Management of complex urban water systems based on Macro-modelling, Simulation and Stakeholder participation-the case of the megacity of Lima. Watermatex – 8th IWA Symposium on Systems Analysis and Integrated Assessment, San Sebastian, 21.-23.06.2011
- Schütze, M. (2013b): LiWatool: Aplicación a Lima: Modelos del Sistema de agua y desagües de Lima y Callao. Documentación; Internal Report; ifak e. V. Magdeburg
- Schütze, M.; Alex, J. (2014): A simulator for model-based participatory integrated urban water management; 13th International Conference on Urban Drainage, Surawak, Malaysia, 7-12 September 2014

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2.6 Specific results – Water Resources Management supported by Capacity Building

Input to this section provided by Prof Artur Mennerich, Campus Suderburg, Ostfalia University of Applied Sciences

2.6.1 Needs

Integrated Water Resources Management (IWRM) in Megacities affected by climate change is usually impeded by diverse factors which amplify the following problems:

1. Uncontrolled population growth
2. Highly social differences which result in basic water needs just for survival up to above-average water consumption as a result of prosperity
3. A lack of sustainable fresh water supply and appropriate waste and waste water treatment in order to preserve future reserves of water due to technical and financial restrictions
4. In general a minor environmental awareness of the complex relationships between fresh water exploitation and waste water discharge in order to preserve future reserves of water Considering integrated IWRM in Lima, there are many local and regional activities of mainly NGO´s and some governmental programs to teach the affected population in basic questions concerning personal water-related responsibility and providing small-scale clean water resources. This is a very important contribution to future water resources management but not a focus point of WP 6 “capacity building”.

On the other hand, there are substantial technical investments in large-scale water supply and discharge infrastructures which are mostly performed by international project partners who provide know how and materials. If there is no long-term contract for maintenance, education of expert staff and supervision the operation of the plants is quite often far below its technical limits.

Professional water treatment plants for the supply of drinking water are usually well equipped and operated with high hygienic standards, but the discharge of sewage and industrial wastewater into surface water used as raw water supply is neglected. Fresh water protection and wastewater treatment is not among the focal points of interest, as it is considered to be costly and the benefits do not always show yield and are not visible as immediate benefit to the people because it is very costly, requires qualified personnel and permanent maintenance and supervision. The aspects of fresh water protection and water reuse opportunities are not exhausted in Lima. It will be necessary to establish a multi-barrier-system-strategy to protect the drinking water resources. In Germany, this system was introduced in the beginning of the 20th century when the country faced a similar situation with increasing population and urbanization.

This is the working approach of WP 6 „Capacity Building“. WP 6 focused on advanced training of technical staff and students in the field of sanitary engineering, especially waste water engineering and water reuse. Whilst much of the work reported in this Section 2.6 is rather specific to the setting in Peru, it might well give inspirations for similar activities in other countries and regions.

Lima has only one National University of Engineering with a department specificially dedicated to Sanitary Engineering: Universidad Nacional de Ingenieria – Facultad Ingenieria Ambiental (UNI-FIA) in Lima. They admit around 50 students per year for this department.

2.6.2 What was done: capacity building in the LiWa project

The training is based on three pillars which are mutually reinforcing:

1. Development of cooperation between Ostfalia University of Applied Sciences, Faculty of Construction-Water-Soil, Department of Sanitary Engineering (OCS) and UNI-FIA to promote **scientific and educational exchange** including **summer schools** (Figure 11) and **mutual project meetings** (Figure 12 and Figure 13).

Figure 11: German and Peruvian Participants of the Summer School 2013 in Lima

Figure 12: Visit of CITRAR (Research Center for Waste Water Treatment and Special Waste Disposal) at UNI-FIA in Lima

Figure 13: Visit of WWTP Braunschweig in Germany

2. Implementation of E-learning modules on the Moodle-based **teaching platform "LiWa e-Academy"** for registered users (https://liwa.ostfalia.de/). The curriculum provides information on waste water treatment, water reuse and hydrological modelling for self-study.

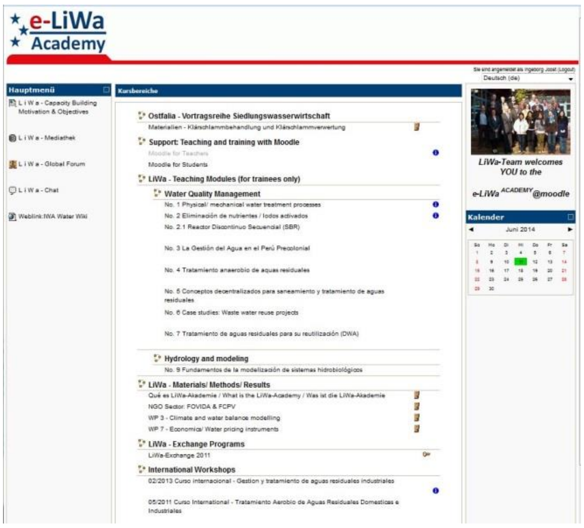

Figure 14: Access to the LiWa-Academy

3. Implementation of one-week training courses for professionals at the site of the Peruvian Engineering Association (Colegio de Ingenieros del Perú) with the support of the Ministry of Housing, Building and Sanitation (Minsterio de Vivienda, Construcción y Saneamiento). The courses included the current state of technology for large-scale municipal and industrial waste water treatment. The audience included engineers such as civil engineers who work as decision makers and planners.

Figure 15: Speakers and Participants at the International LiWa-Seminar on “Management and Treatment of Industrial Wastewater" in February 2013

Figure 16: Speakers and Participants at the International LiWa-Seminar on “Aerobic Treatment of Domestic and Industrial Wastewater" in May 2011

Figure 17: Concentrated audience 2011

Figure 18: And practical experience in the lab during the seminar 2011

2.6.3 Particular successes

The academic exchange was an eye-opener for both partners. The German students got a deep understanding of the problems to face when implementing a project in another country. Some of the problems are bureaucratic, financial, labour and technical differences in project management which slow down the efficiency of a project and might even endanger the long-term success. When working as an engineer these experiences might prevent future failures in international infrastructure projects. The graduate students of Peru appreciated the opportunity to visit German waste water treatment plants and to use the research facilities at the department of OCS. The information on technical and operational parameters, details of process engineering and innovative products enabled a comparative analysis of Peruvian and German standards. There was a mutual respect and fruitful discussion.

Two students from OCS went to Lima to perform their practical work part of their bachelor thesis in waste water treatment, using the facilities and supervision of UNI-FIA. Vice versa Peruvian bachelors and masters visited OCS to perform their research in our laboratories under the supervision of the German LiWa-Partner, financed by DAAD scholarships. A PhD thesis on the use of micro-algae in biological waste water treatment was completed in December 2012. Another PhD thesis on biological phosphorous removal will be submitted in 2015.

An interdisciplinary bachelor thesis project was initiated in 2011 when 4 Ostfalia students of 4 different faculties and course of studies (Social Work, Health Business, Supply Technology, Management of Water & Soil) went to Lima. The task of the team was to create an integrated water supply and discharge concept for a settlement in suburban Lima. The LiWa Partner and NGO Fovida provided the contact data and introduced the team to the municipality. In the end, due to external financial reasons, the project couldn´t be established as planned in the district. Each student wrote their own thesis on different subjects in Lima and already obtained their bachelor degrees.

The teaching support at the LiWa summer school 2013 in “Lima beyond the Parc” integrated academic student activities into a practical local context of a district in Lima. This was learning on the job and a challenge for Peruvian and German students. The project was also with an interdisciplinary context including social workers, landscape architects, urban planners and environmental engineers to design a garden in the desert. The LiWa-Partner ILPOE present the interdisciplinary results later on (see Section 2.8). Concerning irrigation needs, the water reuse team installed a low-cost grey-water treatment system. This low-tech facility with only limited equipment trained the technical improvisation and promoted the skills of dealing with people in disadvantaged districts. Although local people appreciated and supported the activities for improving the local infrastructure, the questions of material theft and maintenance of installations had to be considered.

Since the faculty of environment of UNI-FIA is a project partner of LiWa and, at the same time, UNI-FIA has close links to the Association of Engineers (Colegio de Ingenieros de Perú) in Lima, the expert workshops “train the trainer” were very well organized. The seminars took place in the buildings of “Colegio de Ingenieros” and were fully booked. The lectures were held during the evening hours so that about 40 engineers could attend the course in addition to their daily work. The audiences were very inquiring and dedicated. Since all the engineers were working in technical key positions for waste water infrastructure, it was an effective opportunity to multiply technical skills.

The e-learning system was designed to solve multiple problems with a match. Technical qualification at any time, any place and not limited to certain people. If necessary, there is free advice in the subjects by contacting the project partners. The e-learning system was tested during lectures in Germany and finally promoted during the expert workshops. After finishing self-studies of a module, the participants were asked to answer test questions to review the course content. In the event of awarding a certificate, the participant should perform an exam at an institution like “Colegio de Ingenieros”. OCS and UNI-FIA provided the modules for waste water treatment. Also the DWA (German Water Association) contributed a publication on treatment steps for water reuse. Since all modules are self-contained chapters, any other topic can be still added.

2.6.4 Recommendations for adaptation/application in another city

About the LiWa-e-Academy there were two main objectives which should be considered next time:

Firstly, the language problem was underestimated. The contract language of the LiWa-project was English and all shared documents were written in English. Although English is the official academic language, the majority of Peruvian engineers and scientist do not speak English sufficiently well. All modules had to be translated into Spanish. Whenever possible, technical lecture documents should always be published in the language of the target country to make sure that not only an elite has access to further qualifications. The translations i.e. into Arabic should be made by experienced mother tongue engineers.

Secondly, hard-working people investing additional time to improve their technical skills need an adequate learning environment. The social feedback of a teacher, group dynamic learning processes and a large difference in time between a question asked and the corresponding response are important factors for motivation and successful learning. Since Peruvians have a very sociable nature, direct teaching – in case this is the feasible option - would be the preferred option as opposed to e-learning. It was felt that a computer cannot substitute completely a live lecture of an expert.

In the Peruvian context of WP 6, capacity building focussed on the academic level because there were no other institutions available. The LiWa project was not in touch with technical colleges who educate technicians. Neither Sedapal nor the partners of UNI-FIA were in touch with technical colleges to extend the network of capacity building.

In general, sanitary engineering consists of two sections: the planning of infrastructure and the operating of the infrastructure. The first is an academic job for engineers and scientists and should be organized by consulting experts. The latter is only partly a job for engineers. In Germany a sanitary engineer is the head of a team and manages the waste water treatment plant. Its staff are technicians, preferably specialists for waste water engineering. They plan, monitor, control and document the processes on the plant. In Peru there is no equivalent education available. Because of various reasons, most WWTPs are not operated and documented sufficiently. Although it is cost-intensive to educate and employ specialized technicians in the long run, it is worth the investment.

Capacity building should extend the program to cooperations with technical colleges and exchange programs for technicians.

2.6.5 Additional information

Further reading

- Yaya-Beas, R.E., Wichern, M., Kehl, O., León, C., Schütze, M. (2007): Sustainable water management in a desert megacity on the Coast: Lima Metropolitana – How can education and capacity building contribute to this? „New directions in Urban Water Management“ – UNESCO Conference Paris, 12.-14.09.2007

Contact

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2.7 Specific results – UFZ – Approaches for regulating water use and climate adaptation

Input to this section provided by Dr Paul Lehmann, Department of Economics, UFZ Leipzig

Several frameworks have been developed to understand regulatory challenges and to develop regulatory approaches. These can be applied to and specified for different contexts. Frameworks are related to the regulation of water supply through centralized networks (Section 2.7.1), the regulation of decentralized water supply (Section 2.7.2), and, more broadly, the regulation of adaptation measures to climate change (Section 2.7.3). Moreover, several lessons have been learnt regarding how to actually develop appropriate solutions to local challenges (Section 2.7.4).

This section thus provides several frameworks which inform about (1) available options for designing water tariff option in particular as well as for regulating the water sector in general, Secondly, it outlines relevant barriers which may impair the implementation and the outcome of these options, and, thirdly, it presents an approach to overcome these barriers and provide for an effective regulation of the water sector. These frameworks are thus meant to support the development of regulatory approaches which are appropriate for the local context. To identify useful approaches on the basis of these frameworks, decision makers thus have to check (1) which of suggested options are actually available, (2) whether the outlined potential barriers to their implementation are actually relevant. Based on this evaluation, policy approaches may be arrived which are at the same time effective and feasible to manage the water sector sustainably.

2.7.1 Regulating water tariffs for network-based water supply

Water pricing options to address affordability

Figure 19 presents a typology of water pricing options to address affordability. It is organized along the different components of water price design.

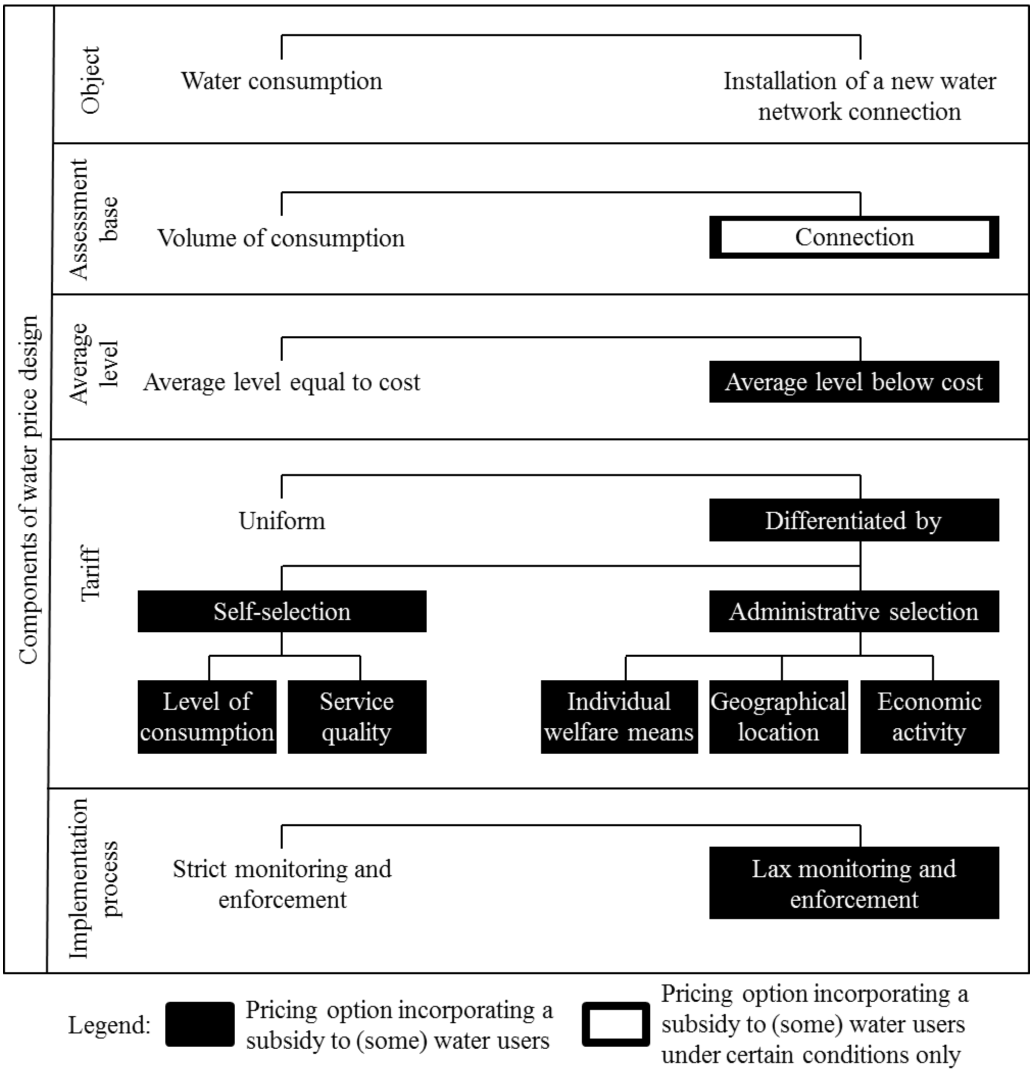

Figure 19: Typology of water pricing options to address affordability

To what extent the diverse options may effectively help to improve the affordability of water supply depends on the characteristics of both the technological and the socio-economic environment into which they are implemented. *Table 5* provides an overview of possible limits.

Further reading:

- Lehmann, P. (2011). “Making Water Affordable to All – A Typology and Evaluation of Options for Urban Water Pricing.” *UFZ Discussion Paper* 10/2011.
- Lecture “The Economics of Water Pricing”, Lecture for the E-Learning Module on Integrated Water Resources Management (IWRM) established under the UNESCO-International Hydrological Programme, the Hydrology and Water Resources Programme of the WMO and the IWAS – International Water Research Alliance Saxony, recorded in Leipzig (Germany), July 14, 2010, www.iwrm-education.org.

Special case study: Increasing block tariffs vs. means-tested tariffs

Tariff discrimination is the major means to safeguard affordability of water supply in many countries throughout the world. The dominant approach of tariff discrimination uses Increasing Block Tariffs (IBTs). With IBTs, the marginal price of water increases stepwise with the quantity of water consumed. Therefore, consumers of small quantities - which are assumed to be poor with this type of tariff discrimination - face smaller prices per cubic meter than consumers of large quantities of water. Yet this approach is nowadays commonly criticized for being insufficiently targeted to the poor. As a response to this deficiency, means-tested tariffs are increasingly considered and have been implemented in some countries, such as Chile. They are expected to be better targeted to poor customers as the tariff discriminates on the basis of individual welfare means.

An empirical analysis reveals that there may be trade-offs between using IBTs and means-tested tariffs: From a pro-poor perspective, it is ambivalent whether it is preferable to make more poor customers receive subsidies (as under an IBT tariff) or to increase the transfers to those poor actually subsidized to effectively mitigate affordability problems (as under a means-tested tariff).

It is also important to consider that experiences with different tariff designs in specific countries cannot be easily transferred to other contexts. The specific details of designing the targeting mechanism, i.e. the size of the lifeline block, the block prices, the means test, and the decision how to combine these within one tariff scheme, are decisive for the actual income redistribution. What is more, the results also crucially depend on the consumption pattern of consumers. These are a function of local environments. A generalizable result is that understanding and, most important for policy advice, predicting the effects of IBTs is clearly more complex than with uniform means-tested tariffs because IBTs combine most of the aforementioned design factors. The interplay of tariff design and local consumption patterns may even make IBTs unusable for clear-cut policy measures.

Further reading:

- Barde, J.A., Lehmann, P. (2013). Distributional Effects of Water Tariff Reforms – An Empirical Study for Lima, Peru. *Water Resources & Economics* 6: 30-57. Previous version also available as *UFZ Discussion Paper* 14/2013.

Components of price design	Pricing options		Limits associated with the technological environment	Limits associated with the socio-economic environment
Object of pricing	Water consumption (subsidized consumption charge)		- Low connection rate among the poor	
	Installation of a new connection to the water network (subsidized connection charge)		- Lack of network in poor neighbourhoods - High need (and cost) of additional intra-household fixtures	- Lack of legal land title among the poor - Inability to provide security deposit - Incompatibility between utility payments and income streams among the poor
Assessment base	Consumption charge	per volume of consumption	- Low metering rate among the poor	
		per connection	- Low rate of shared connections among the poor	- Low per-capita consumption of poor - Small/average size of poor families
	Connection charge per connection			
Average price level	Reduced single-part price			
	Two-part price	Fixed charge reduced, volumetric charge not reduced		
		Fixed charge reduced, volumetric charge increased	- High rate of shared connections among the poor	- High per-capita consumption of the poor - Large size of poor families
		Menu		
Tariff	Self-selected differentiation by consumption	Without consideration of user no. per connection	- High rate of shared connections among the poor	- High per-capita consumption of the poor - Large size of poor families - Resale of water to neighbours
		With consideration of user no. per connection		
	Self-selected differentiation by service		- Lack of public stand pipes available to the poor	- Low willingness to accept low-quality service
	Administrative differentiation by individual welfare means			
	Administrative differentiation by geographical location			- High heterogeneity of income levels within neighbourhoods
	Administrative differentiation by economic activity			
Implementation process	Lax monitoring and enforcement			- High risk aversion among the poor

Table 5: Possible limits to achieving affordability for different water pricing options

Political barriers to water tariff reforms

It is often assumed that the political process is directed towards increasing societal welfare. However, practical political decisions are influenced by the self-interest driven behaviour of the diverse political actors and stakeholders: politicians, regulators, water suppliers and water users (who are also voters). These interests need to be taken into account to understand barriers and opportunities for water tariff reforms. Figure 20 provides an overview of the relevant actors and their interests.

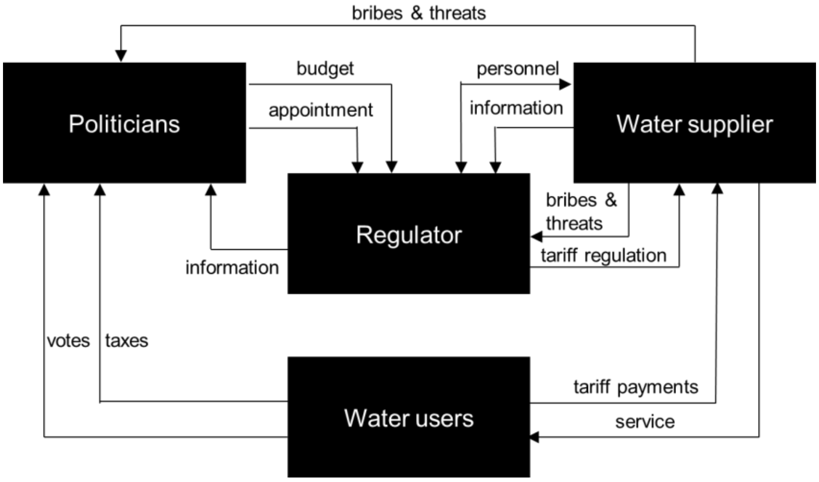

Figure 20: Political actors and their interrelations in the water sector

This framework allows deriving several hypotheses about the impact of actors' interests on water pricing:

- The water supplier has an incentive to set a price above that of perfect competition and capture as much as possible of the monopolistic rent.
- Water users connected to the network tend to prefer lower tariffs (if a certain service level can also be maintained by other funding sources, such as taxes or transfers), water users not connected to the network should prefer tariff increases which allow network extensions.
- Politicians act as transfer brokers between the water supplier (from which they may receive financial support/bribes) and the water users (by whom they are elected). The eventual effect on the tariff level is ambiguous depending on which group exerts a stronger influence.
- Regulators may set tariffs higher than the efficient level in the case of regulatory capture (bribes from water supplier, exchange of personnel).

Further reading:

- Felgendreher, S., Lehmann, P. (2012). "The Political Economy of the Peruvian Urban Water Sector." *UFZ Discussion Paper* 18/2012.

2.7.2 Regulating decentralized water supply

Apart from regulating water tariffs for network supply, another important concern in the water sector is to provide access to safe drinking water and basic sanitation to the entire population. Typically, the preferred approach is to extend centralized networks to supply all population. This aim notwithstanding, reaching 100 % coverage through centralized water networks is unlikely in many contexts, particularly in developing countries. This may be due to a diverse set of constraints associated with water supply (see Figure 21) as well as demand (see Figure 22).

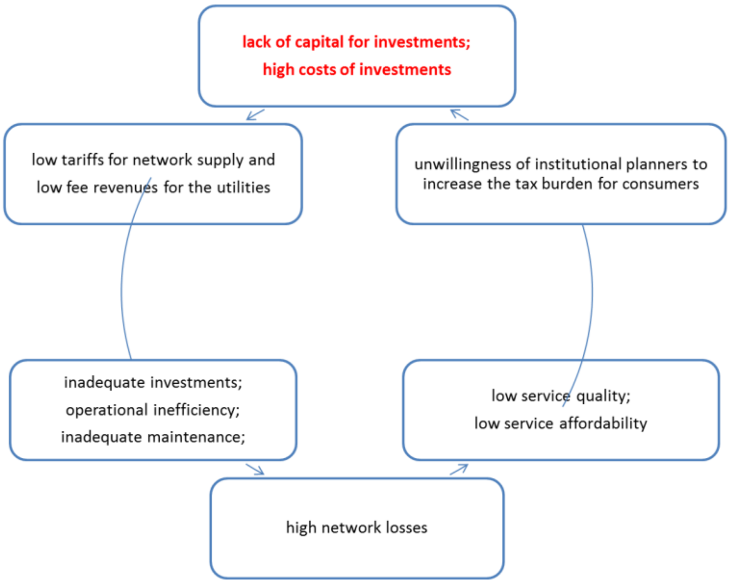

Figure 21: Reasons for insufficient network supply

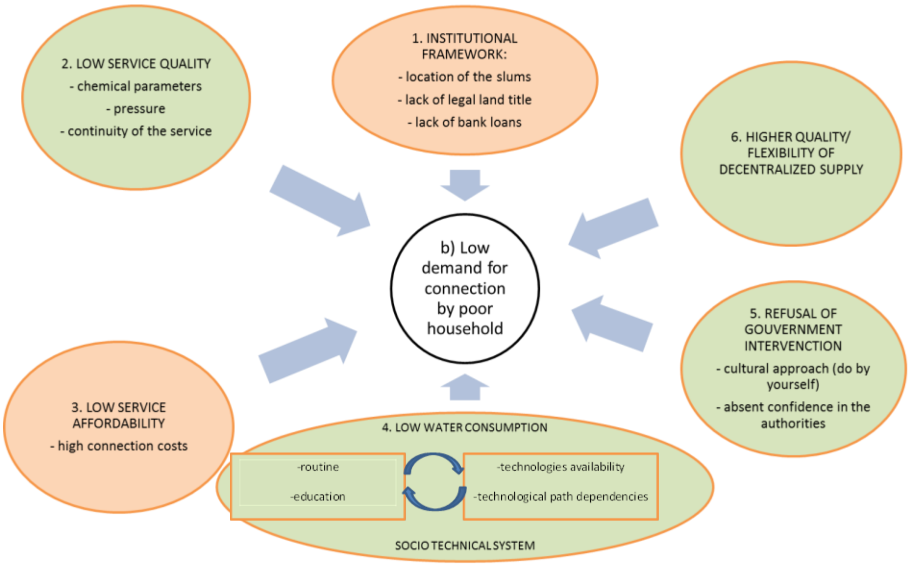

Figure 22: Reasons for low demand for network supply

This implies that a certain share of water users need to be supplied by decentralized means of supply, such as wells, water kiosks and water vendors, at least in the short and medium term. Consequently, political efforts should not solely focus of extending water networks but also more strongly on addressing the challenges associated with decentralized means of water supply directly. Relevant challenges include:

- Prices that are typically higher than for network supply for a variety of reasons: (1) absence of subsidies, (2) economies of scale in centralized networks, (3) monopolies of water vendors

- Negative externalities including (1) diseases due to low quality and quantity of water supply, (2) time spent on collecting water, (3) social-gender disparities in the task of fetching water

Against the background of these challenges, a regulatory approach for decentralized water supply most likely needs to involve a mix of top-down as well as bottom-up solutions (see *Table 6*).

Table 6: Approaches to regulate decentralized water supply

Top-down approaches	Bottom-up approaches
• Price discount for public standpipes • Concessions for water tankers • Monitoring of water tankers • Subsidies to the acquisition of new water tankers • Modification of the legal framework for land tenure • Formal recognition of the relevance of decentralized water supply in policy-making in general • Implementation of effective urban planning • Education and capacity building	• Water tanker associations • Water user associations • Neighbourhood supervision committees • Participation of water sector stakeholders in political decision-making

2.7.3 Overcoming barriers to urban adaptation to climate change

Figure 23 depicts an analytical framework which may be employed to understand possible barriers to adaptation to climate change in cities – and also to elaborate on possible opportunities for promoting adapation. The framework shows that whether or not appropriate decisions are taken depends on the information, resources and incentives of decision-makers (see *Table 7*). These drivers are themselves functions of several underlying factors: the characteristics of the actors, the institutional environment as well as the natural and socio-economic environment (see *Table 8*).

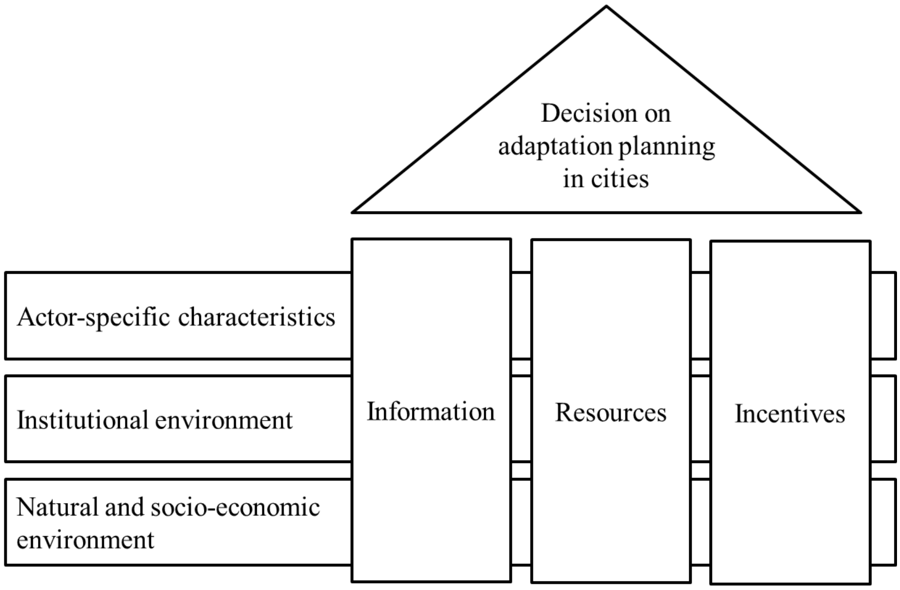

Figure 23: Variables influencing decisions on adaptation planning in cities

Table 7: First-tier sets of variables and examples

Information	Resources	Incentives
• On climate stimulus • On impacts of climate change • On available adaptation options • On costs and benefits of adaptation options	• Financial means • Personnel • Staff expertise • Time	• Balance of costs and benefits of adaptation • Co-costs/-benefits with other objectives of action • Positive/negative externalities of action

Table 8: Second-tier sets of variables and examples

Actor-specific characteristics	Institutional environment	Natural and socio-economic environment
• Perceptions • Preferences • Experiences • Knowledge • Leadership	• Formal and informal institutions, specifying e.g. multi-level governance, mainstreaming of adaptation, participation and organizational routines	• Intensity, velocity, spatial and temporal scale of impacts of climate change • Certainty regarding these patterns • Number of actors affected • Level of economic development • Demographic patterns

Further reading:

- Gawel, E., Heuson, C., Lehmann, P. (2012). “Efficient public adaptation to climate change – An investigation of drivers and barriers from a Public Choice perspective.” UFZ Discussion Paper 14/2012, Helmholtz-Centre for Environmental Research – UFZ, Leipzig. Available online: http://www.ufz.de/export/data/global/40437_14%202012%20Heuson_Gawel_Barriers%20Eff%20Pub%20Ad_gesamt_internet.pdf
- Heuson, C., Gawel, E., Lehmann, P. (2014). “State of the art on the economics of adaptation.” In Markandya, A., Galarraga, I., Sainz de Murieta, E. (eds.), Routledge Handbook on Economics of Adaptation to Climate Change, London: Routledge, pp. 27-55.
- Heuson, C., Gawel, E., Gebhardt, O., Hansjürgens, B., Lehmann, P., Meyer, V., Schwarze, R. (2012). “Fundamental Questions on the Economics of Climate Adaptation - Outlines of a New Research Programme.” UFZ Report 05/2012, Helmholtz-Centre for Environmental Research – UFZ, Leipzig, 2012. Available online: http://www.ufz.de/export/data/global/33394_UFZ_Report_Climate_Adaptation_final.pdf
- Lehmann, P., Brenck, M., Gebhardt, O., Schaller, S., Süßbauer, E. “Barriers and Opportunities for Urban Adaptation Planning: Analytical Framework and Evidence from Cities in Latin America and Germany.” Mitigation and Adaptation Strategies for Global Change 20(1): 75-97Mitigation and Adaptation Strategies for Global Change, DOI: 10.1007/s11027-013-9480-0. Previous version also available as UFZ Discussion Paper 19/2012.

2.7.4 General lessons for implementing solutions and research

Learn from experiences made elsewhere

Often, solutions to certain water-related problems have already been developed for other regional contexts. It may be worthwhile to collect and review these experiences to further develop strategies for a specific regional context and to instruct corresponding research. In the context of the LiWa project, it proved to be particularly helpful to allow representatives of the regulatory authority SUNASS to visit research institutions abroad to be able to dedicate time to research and to learn from international experiences. Correspondingly, funds should be provided or applied for to allow such research stays.

Design water policies for their specific local context

While it is generally a good idea to rely on those solutions that have proven effective in certain situations/to be suitable, careful knowledge transfer is necessary when implementation is considered elsewhere. The performance of policies crucially depends on the specific local context in which they are being embedded. Consequently, when designing and implementing environmental programs, strategies and policies as well as related research programs, the specific local environmental and socio-economic conditions require particular consideration.

Use sustainability impact assessments to design water policies

The evaluation of water-related policies and planning processes focusses strongly on environmental and economic impacts. This perspective is insufficient given the inseparability of social and natural systems, the relevance of social costs and the importance of resources for sustaining human livelihoods, cultures and health. Consequently, a more comprehensive consideration of social and economic aspects along with environmental ones is required to address concerns of fairness, social inclusion and gender equality as well as economic performance. Such an approach provides a broader picture of possible impacts and synergy effects. It is fundamental to ensure efficient and cost-effective design and implementation of environmental policies. Moreover, carefully carried out Sustainability Impact Assessment (SIA) processes also allow a participation of a much broader spectrum of stakeholders and affected groups, which in turn facilitates the acceptance of decisions.

Mainstream water policies

Policies and spatial plans to address water-related problems are primarily designed by environmental departments and agencies. This may bring about the risk that interactions with other sectoral policy fields and administrations are not properly considered. This may impair implementation and lead to adverse incentives and unintended negative effects in other fields. Consequently, successful environmental policies need to be present not only in exclusively environmental institutions, but also to be mainstreamed in all other affected agencies and departments, including those involved in health, agriculture, the economy, and social, security or education matters. In addition, the environmental and water sector needs to be informed by other sectoral policies to take their stakes into consideration to improve decision-making. Thus, institutions need to be established which allow for collaboration and exchange between different policy fields.

Integrate water policies across spatial scales

Environmental policies can be adopted by local, regional, national and international governments and organizations, but overlapping or unclear responsibilities lead to inefficiencies and may hamper their performance. Moreover, policies implemented at the local level may neglect interdependencies that occur between regions – and national policies may fail to properly take into account local particularities. Therefore, policy decisions require strong coordination across different administrative levels. In addition, the spatial scale of policies must correspond to that of natural units and processes, such as watersheds or pollution flows, but also with areas of urban-rural interaction (i.e. commuting, exchange of goods and services, etc.). This is particularly important for urban and metropolitan areas which strongly depend on ecosystem services provided by their hinterland, e.g. water supply. Consequently, both, clear spatial information about natural systems and new modes of coordination and cooperation between administrative bodies within a common natural system are necessary to ensure fair and balanced spatial distribution of costs and benefits of environmental policies.

Develop and apply bottom-up, participatory approaches

Policies are often implemented as top-down approaches which do not take into account local realities, challenges, and problems. Therefore, it is crucial to develop and promote bottom-up, community-based approaches. This can be achieved by the involvement of local government institutions and authorities, civil society organizations, the scientific community, the business sector, as well as through the inclusive participation of the population affected. One specific strategy could be the formation of working groups containing all stakeholders. Such groups should have a clear mandate for policy-making. However, bottom-up approaches are in risk to be hollowed out by simple not-in-my-backyard (NIMBY) motivations, serving exclusive individual and local community interests. Therefore it is necessary to find planning and policy processes, which are capable to balance community-based and hierarchical regional implementation competencies (“top-down”) which are able to take larger-scale society interests into consideration.

Use local knowledge to promote education and provide local opportunities for learning

The solution to many water-related problems depends on passing key behavioral messages and raising the public’s awareness. In this respect, however, the focus of children and adult education systems is often far from the realities of people, being too abstract and rarely directly applicable. The established perceptions of the public require enhanced consideration as a basis for environmental education approaches. Cultural and social characteristics can considerably shape the effectiveness of educational policies. To promote education, policy makers should therefore ensure the inclusion of local knowledge and participatory approaches. In addition, experimental learning, for example through the experience of urban wilderness, participation in water conservation projects, and demonstration of (pilot) technologies close to where people live, can help increase their understanding of how they influence and depend on ecosystems. In this way, though indirectly, local opportunities for learning can increase people’s commitment and responsibility towards environmental stewardship. Water in particular provides far-reaching educational opportunities, as the cyclic processes involved in its transformations are vividly showing the interdependence of ecological and social systems.

Promote long-term thinking and implementation

Policies and solutions are typically formulated and implemented by short-term projects. However, environmental problems are complex and call for long-term thinking and long-term strategies. Post-project monitoring and evaluation must be foreseen in project planning, and necessary budgets must be provided. Moreover, long-term thinking points to the need for policies to be designed in a way that they can adapt to changes in environmental and socio-economic conditions. In this regard, the duration of natural cycles, but also dynamic demographic or economic trends have to be taken into account. Such adaptive management requires flexible administrative bodies and the continuous involvement of stakeholders, science and interested parties.

Improve access to available data

Access to water-related data is often restricted, even though public funds are provided for data collection by governmental, administrative and research institutions. Easy access to such data should be the rule rather than the exception, not only for scientists, but for the interested public and other stakeholders as well. Consequently, agencies managing data should be affiliated to research projects, either as official project partner or by additional agreements.

Adapt environmental monitoring to urban areas

When analysing urban water systems, data collection needs to take into account the high spatial and temporal variation and dynamic changes in the physical and socio-economic environment that are typical for such settings. For example, hydrological models require more and specific data to characterize urban catchments than rural catchments due to the heterogeneity of land cover even in small areas. Today, information in different fields (e.g., land use, ecology and human health) is typically collected separately, resulting in spatial and temporal mismatches. Harmonized collection and storing of data would allow for more holistic research approaches and more sustainable interventions. This requires a closer cooperation on different levels between different sectors, administrative bodies, organizations and scientific institutions different administrative and scientific institutions.

Integrate qualitative data into models

Models aiming at the prediction of water-related impacts are numerical and frequently exclude qualitative data, such as socio-economic information. For a more holistic representation of reality, strategies need to be developed in order to include such information into models. This is particularly relevant in urban settings where the behaviour of people can only partly be captured by quantitative or categorical indicators. Solutions to this challenge require a closer cooperation between modellers and social scientists than is presently the case.

Further reading:

- Anthonj, C, Beskow, S., Dornelles, F., Fushita, A., Galharte, C., Galvão, P., Gatti Junior, P., Gücker, B., Hildebrandt, A., Karthe, D., Knillmann, S., Kotsila, P., Krauze, K., Leal Silva, A., Lehmann, P., Moura, P., Periotto, N., Rodrigues Filho, J., dos Santos, D., Selge, F., Silva, T., Soares, R., Strohbach, M., Suhogusoff, A., Wahnfried, I., Zandonà, E., Zasada, I. (2014). "Water in Urban Regions: Building Future Knowledge to Integrate Land Use, Ecosystem Services and Human Health". Science Policy Report. Rio de Janeiro/Berlin/Halle: Academia Brasileira de Ciencias/Die Junge Akademie/German National Academy of Sciences Leopoldina. Available online: http://www.leopoldina.org/uploads/tx_leopublication/2014_Policy_Paper_GermanyBrazil.pdf

Addtional information

Further reading: Information has been provided within the individual sections.

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2.8 Specific results – ecological infrastructure strategy

Input to this section provided by Dr Bernd Eisenberg, ILPOE, University of Stuttgart.

An integrated urban planning strategy was developed in order to facilitate the implementation of an “Ecological Infrastructure” for the metropolitan area of Lima on different scales and was described as the Lima Ecological Infrastructure Strategy (LEIS). The main components of the strategy include the following: the definition of principles for the large-scale city-region level and their harmonisation with the local urban planning instruments; the GIS-based spatial analyses, planning and quantification tool for the development of the spatial layout of the Ecological Infrastructure based on the urban water cycle and open space analyses; and the manual with recommendations on water sensitive urban design.

The applicability of the concept to a real situation has already been proven with the development of a pilot project. The “Ecological Infrastructure” approach and the integrated planning strategy with the methodologies of the key components can be adopted and applied in other areas with similar context. A “LEIS Manual” has been complied, which – with its straight forward prototype design solutions for specific “hydro urban characteristics” – is easily adaptable to other conditions. An initial study in the area of New Cairo, Egypt has already been conducted.

2.8.1 Ecological infrastructure concept

The “Ecological Infrastructure” concept is based on Green Infrastructure Thinking and the methodology of Water Sensitive Urban Design. The resulting “Ecological Infrastructure” of a city or a region can be described as a multifunctional system of open spaces that integrates ecological processes with the water cycle (Figure 24). Thanks to its multiple functions, it can sustain and resist the pressures of urbanization and support the urban water cycle, thus it can guide urban development in a water-sensitive way. It is assumed that the coordinated designation of multifunctional open spaces tackles the challenges of urban development and land-use planning more efficiently than conventional approaches. However, following the concept does not reduce the development pressure *per se*, but it guides it to areas that are less vulnerable.

Ecological infrastructure consists of various ecosystem functions; it seeks to protect and strengthen them by embedding them in a multifunctional open space system, which is eventually ‘strong’ enough to resist urban pressure. The ecological infrastructure considers the hydrological cycles, it re-establishes ecological processes and it increases essential environmental services in the city, thus improving the urban environment and guiding urban development in a sustainable way.

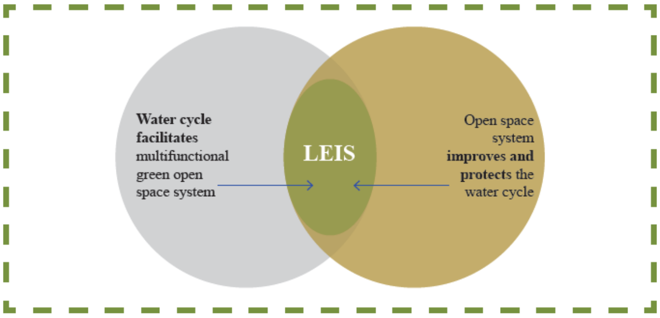

Figure 24: Integration of open space and urban water cycle (ILPOE)

2.8.2 (Lima) Ecological infrastructure strategy

Generally speaking, the EI Strategy is a new approach towards sustainable urban development, which integrates water and wastewater management with the existing disposition of open spaces, creating a new and strong multifunctional open space system that can resist traditional informal occupation processes and give coherence to the city. The strategy integrates landscape planning, urban planning, and water and wastewater management, giving due and balanced consideration to social, economic and environmental factors, and involving local authorities and community organizations. It stresses the need to adapt the current means of urban water management to a dry context, considering the city as a ‘water source’ and as a ‘catchment area’, promoting the reuse of wastewater and non-potable water, especially for irrigation, contributing to close the urban water cycle in the city, increasing green areas in a sustainable way and at same time, the provision of ecosystem services, creating the resilience to cope with climate change.

The EI Strategy describes the relationships between interacting levels of organization within a coherent spatial framework, from the macro-scale (overall catchments of the metropolitan area), to the meso-scale (different landscape and urban typologies of the metropolitan area) and the micro-scale (project sites). Thus the EI Strategy proposes integrative solutions related to water, landscape planning and open space design through three main components that are interconnected and that cross-fertilise into each other.

These three main components can be described as follows:

(1) A set of Principles which contain main objectives and cover their implementation within the institutional and legal framework through the various planning instruments: Participation of local stakeholders and institutions is necessary throughout the whole process and with regard to all three components, but it is of paramount importance that these principles be implemented in consultation with local views and needs;
(2) The GIS-based spatial planning and quantification tool which supports the spatial analysis of the urban water cycle and built environment and the identification of the spatial framework of EI: Here the questions of quantification of water demand and supply and localization of the spatial potentials are the central concern using the meso-scale analyses.
(3) The Water sensitive urban design manual which illustrates how to put the proposed objectives into practice in an effective manner, according to local specifics: It adapts the water sensitive urban design methodology to the context (in the case of Lima the arid context) and develops it further in relation to local hydro-urban characteristics.

Principles

The principles are developed as a set of rules for water sensitive urban development within a multifunctional open space system that considers the integral management of water and wastewater. The principles are the following:

- Principle 1. Protect, develop and implement ecological infrastructure, considering availability and integral management of water resources.
- Principle 2. Protect and preserve agricultural land and add value to transform it as urban agriculture improving ecosystem performance, water infiltration and aquifers recharge.
- Principle 3. Transform high risk areas as part of the ecological infrastructure framework considering a sustainable and resilient approach.
- Principle 4. Promote a water sensitive urban development that considers water catchment, saving, treatment and reuse over existent open space in the urban structure increasing green areas and ecosystem services provision in the city.

- Principle 5. Integral and sustainable city management including city vision for a water sensitive urban development with a sustainable and resilient approach.

After defining the principles, the identification of “Where to develop the EI?” is required. Following the principles, the GIS-based spatial analyses, planning and quantification tool supports the establishment of the layout and assessment functions of the EI. It estimates water-related impacts of urban growth and quantifies assumptions on water demand and water re-use potentials of design solution test cases. The manual provides recommendations how to improve the urban water cycle by design of open space on a project level.

With this approach, integrated planning is not only applied in the sense that there is an integration of water management with urban planning and design, but also with regard to the integration of scales, and most importantly through the interlinking of the three components (Figure 25). The whole strategy is documented in a book *Lima Ecological Infrastructure Strategy* (Eisenberg et al., 2014) and provided in Spanish and in English so that it can be implemented in Metropolitan Lima (see also issuu.com/ILPOE). The LEIS book provides also a very good example for cities with similar conditions. The LEIS book and related products can be downloaded from the ‘database on products and tools’ to be found on www.future-megacities.org.

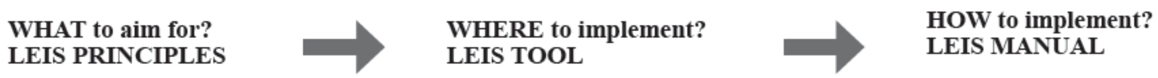

Figure 25: EI Strategy components relation (ILPOE)

Spatial planning and tools

It is essential to identify the areas that have the potential to create the EI. Potentially, the EI consists of all open spaces. The main criterion for selection is their potential for delivering an ecosystem service to the metropolitan area However, the ecosystem services investigated most closely are those related to the services of the urban water cycle (provision of water, purification and treatment of water) and cultural services (recreational and aesthetic experiences) and their interactions.

One of the obstacles to integrated planning consists in the lack of a unified view of the city that is shared by urban and open space planners and water management alike is. The described methodology leads to the creation of meso-scale spatial units that define different typologies of urban spaces with relation to the urban water cycle, and provide guidance for the planning processes of both disciplines. The less detailed meso-scale analyses were developed to overcome the challenges the project was dealing with in Metropolitan Lima, which are in similar in other cities as well:

- divergent spatial information depending on the field of interest, multiple scales, changing resolution and the incompleteness of information remains.
- Weak metropolitan (regional) planning institutions, historically fairly independent district (local) municipalities and, a strong sectoral organisation of spatial, social and infrastructure issues.
- Basic cadastral information from various sources is often at variance and a unified view of the city is lacking.

- The administrative entities (districts) are too diverse in terms of different urban conditions to be useful for any citywide comparison.
- Administrative division force administrative borders onto the city that are hardly recognizable on the ground, but have a deleterious impact on the availability and the harmonisation of information.

In the case of Lima, the water management sectors (approx. 440, average 20.000 pop.) that are used by the water company SEDAPAL for managing the distribution of potable water have been chosen as a meso-scale unit. For other cities, a spatial unit of similar size, either based on administrative or water management units would be appropriate. Applying the GIS-procedures of overlaying information, clustering, disaggregating and aggregating of data to those spatial units, they describe the city according to the water sources and the characteristics of the built and natural environments, including open spaces. The hydro-urban units consist of aggregated and disaggregated information, derived from topography, natural and man-made water sources, population statistics, the state of water infrastructure, structure of urban pattern and open space and environmental functions. They can be categorised under the headings of ‘Water Demand’, ‘Water Supply’ and ‘Natural and urban environment’ including population and society. Consideration of accurate data on each results in specific hydro-urban characteristics; the combination of all relevant aspects eventually leads to a set of distinct hydro-urban typologies that are understood by urban planners and water management as a basis for their analyses, programs and projects.

The analyses are developed following the defined principles. The meso–scale analysis based on Hydro-Urban Units is adequate to localize specific demands for water consumption as well as the divergent potentials for water sources. See for example Figure 26.

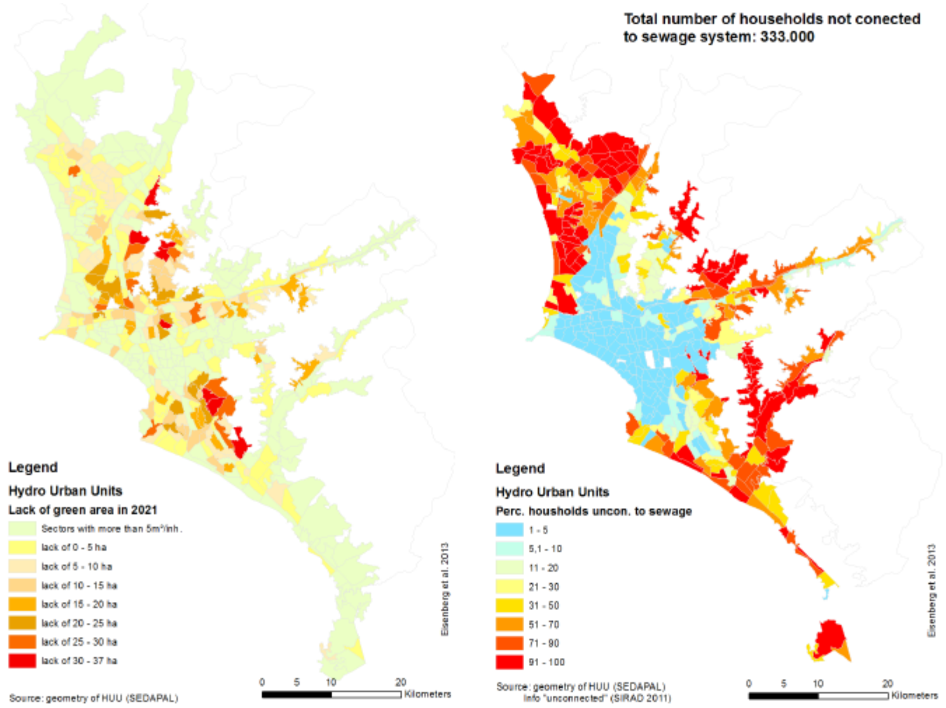

Figure 26: For the hydro urban units of Metropolitan Lima the first map shows the lack of green areas in 2021 and second map shows the percentage of households not connected to sewers. (ILPOE)

Additionally, in order to provide an independent information system, the LEIS-Reporting-Tool - a stand-alone GIS application that provides the spatial analyses information gathered during the project – was developed. It enables the user to access, query and print selected information about the Ecological Infrastructure framework and the (water) sector based analyses. In order to get *ad hoc* information about the present and potential future water demand for green areas, a special tool function was developed that calculates the water demand for a freely selectable area. The tool requires information about the total green area and population per sector, and calculates the water demand based on any given planning scenario for the green ratio (m^2/inhabitant), water demand and population growth. As output results, there are tables and maps that can be used for further analyses or presentations. The LEIS Reporting Tool will be made available for download from the ‘database on products and tools’ to be found on www.future-megacities.org. Depending on the data availability, the reporting tool could be adapted easily to other cities and regions.

Water Sensitive Urban Design Manual

The Water Sensitive Urban Desgin Manual provides design recommendations for treatment and reuse of wastewater (including insufficiently treated wastewater, raw domestic wastewater, grey water and surface water) and its integration into the open space system in order to contribute to closing and improving of urban water cycle within the city. The manual provides a platform for a joint understanding of problems and for joint development of ideas among the different disciplines. One target group are professionals at the public sector from the local agencies at regional, provincial and district level in charge of open spaces planning and design, water infrastructure planning and environmental planning. Another target group are professionals in the private sectors involved with planning and designing of the urban environment.

The key aspect of the development of the water sensitive urban design recommendations was a setup of an interdisciplinary working group including fields as sanitary engineering, environmental engineering, landscape architecture and urbanism, supported by the local authorities. Without local knowledge and local support, transferability is doomed to fail.

The results of the working group were structured and developed into three main parts guided by three leading questions:

- How to save water by design of open space?
- How to treat polluted water by design of open space?
- How to water sensitive urban design in different urban settings?

In order to lower the demand of water for irrigation of green areas, firstly information was provided and visualised about the water demand of different vegetation categories using different irrigation schemes, water quality requirements were provided, so that designers and planer can consider it in the design process (see Figure 27).

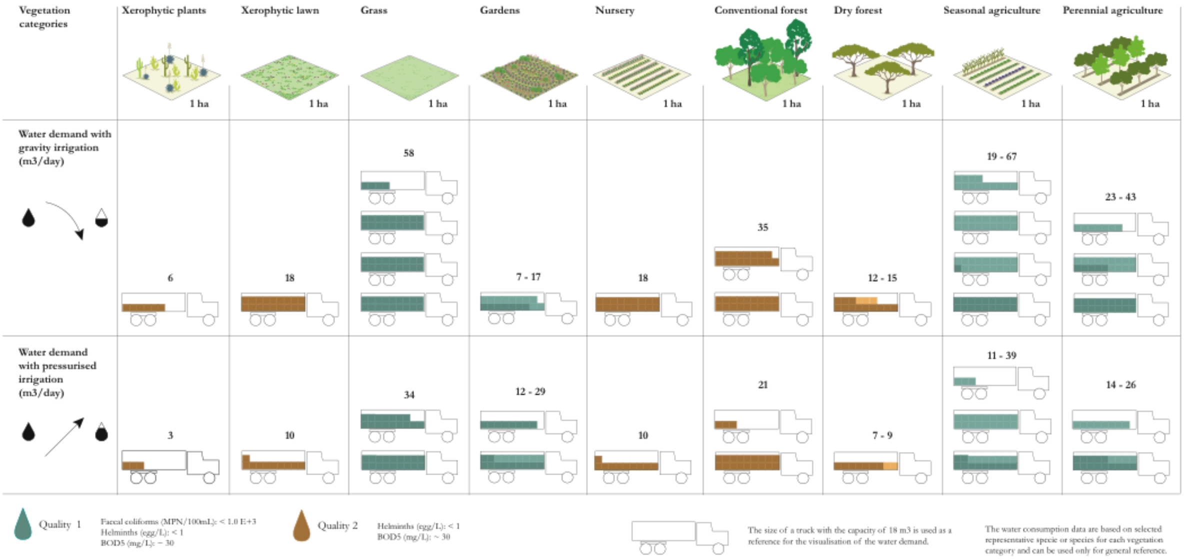

Figure 27: Water demand and water quality requirements for irrigation of vegetation categories in Metropolitan Lima (ILPOE)

Secondly, a *Water demand calculation and design-testing tool* was developed. The water demand tool can be downloaded from the LiWa and Future Megacities Webpage. This Excel-based tool contains pre-defined values (water demand and water quality) and functions. Those values are specific for the climatic conditions of Lima. However, they can be easily updated or extended of new data for different kind of vegetation, or replaced with data for area with different climatic conditions. The tool can be applied in the design process to quickly and inexpensively calculate rough estimates of how much water the planned open space will need for irrigation. Having the ability to calculate water demand of different variations of the vegetation schemes helps designers and planners to create green open spaces that demand less water.

The working group identified wastewater treatment technologies recommended for water sensitive urban design. They developed water sensitive urban design guidelines that aim for integrating the water cycle and wastewater treatment technologies (activated sludge, constructed wetlands and others) into the urban and open space design. One important result were estimations of space demand of treatment technologies for treatment of the water sources “insufficiently treated wastewater”, “raw domestic wastewater”, “grey water” and “surface water”. Those estimations can be used in other conditions as well.

Distinct urban settings were defined based on the differences in the geomorphology (slope), in the hydrological aspects including availability of water sources, the state of water infrastructure, and in the urban structure including the level of consolidation, the open space typologies and their condition. See Figure 28 for the overview of the urban settings.

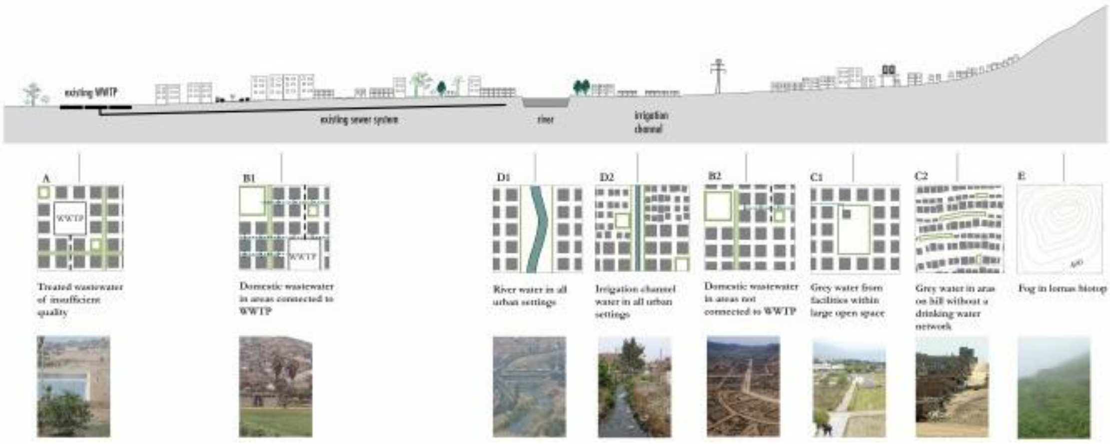

Figure 28: Overview of identified urban settings with different water sources in Metropolitan Lima (ILPOE)

For each urban setting, a portrait visualizes the current conditions. Furthermore, a complementary portrait visualizes the proposed water sensitive development. It is described how the current water cycle can be altered to become water sensitive, recommendations for suitable treatment technology and open space development are provided. A map shows potential areas for implementation of the described measure in a larger scale and a design proposal demonstrates how the recommendations can be applied in a concrete project. The user of the manual has to select one or more of the situations that are the most relevant to her or his planned area. The context-oriented design prototypes are specific to Lima. However, the definition of the urban settings and the development of potential water sensitive solutions is easily transferable.

2.8.3 Demonstration area

A demonstration area was selected for the application of the EI Strategy to show and discuss the strategy with the local stakeholders and so promote the implementation of the strategy in a larger scale. In a feedback loop the findings from the work in the demonstration area contributed to shape the water sensitive urban design recommendations. The strategy was applied working closely with the local district administration and through different scales. Results were the landscape framework plan for the lower Chillon river valley and the Water Treatment Park – Children's Park which was implemented as a pilot project (**Fehler! Verweisquelle konnte nicht gefunden werden.**). Additionally temporary installations of water sensitive urban design were developed during academic summer schools as well as planning and design proposals were developed in a design studio of architecture students.

The pilot project, developed in a participative design process, demonstrates the treatment the polluted irrigation channels for irrigation of parks and the combination of a treatment facility in a recreation area. The project aims to catalyze the implementation of water sensitive open space systems at a larger scale.

Figure 29: Pilot project Wastewater treatment park - Children's Park: Participatory design process and overview

2.8.4 Conclusion

As in all projects, the specific characteristics of the site and the environmental as well as cultural conditions shape the outcome very much. Also in the case of the Lima Ecological Infrastructure Strategy, this is not different. However, the transferability of the results and of the tools was always envisaged and the concise presentation of the interlinked outcomes of this part of the project make it easy for decision makers in a similar situation to follow the idea of what to aim for, where to implement it and how to implement it. The way the principles were achieved was specific to Lima, in very few other cities with more than 9 million inhabitants a regional concerted development plan could be produced in such a short period of time, in a way that open for ideas from civic society as well as from the research community. Still the principles that were developed along that process are straightforward and can be adapted to other conditions. The spatial analyses was based on local information and limited due to the accessibility of data. In other cities the situation may be better or worse, but urban planners and water managers need to agree on a unified view on the city in any case, the spatial analyses and the developed tools propose a way how to do it. Finally, the very elaborated and site specific prototype designs based on results from interdisciplinary working groups are a striking example of how to illustrate the approach as well as very usefulness for everyday tasks.

2.8.5 Additional information

Documents and tools will be made available from the Future Megacities website.

Further reading:

- Eisenberg, B., Nemcova, E., Poblet, R., Stokman, A. (2014): Lima Ecological Infrastructure Strategy, Integrated urban planning and design tools for water scarce cities, Institute of Landscape Planning and Ecology, Stuttgart http://issuu.com/ILPOE
- Eisenberg, B., Nemcova, E., Poblet, R., Stokman, A. (2014): In: Space, Planning and Design, Integrated Planning and Design Solutions for Future Megacities, Vol. 5, Jovis Verlag GmbH, Berlin, p. 27-32, p. 79-86, p. 139-163.
- Poblet, R., Eisenberg B., Nemcova E., Stokman A., Schütze, M., Leon, C. (2013): Water-sensitive urban planning and design solutions for arid context: The Lima Ecological Infrastructure Strategy. IWW Amsterdam, 4. – 8.11. 2013 (http://www.iwawaterwiki.org/xwiki/bin/download/EventsExtra/WaterSensitiveUrbanPlanningDesignSolutionsforAridContexttheLimaEcologicalInfrastructureStrategy/Watersensitiveurbanplanninganddesignsolutionsforaridcontext.TheLimaecologicalinfrastructurestrategy%2DR.Poblet.pdf)

- Video: Summer school 1: http://vimeo.com/62033696
- Video: Summer school 2: http://vimeo.com/63071828
- Blog: http://limabeyondthepark.wordpress.com/
- Blog: https://www.facebook.com/summerschoolbeyondthepark

Additional material can also be found on the following webpage:

- http://issuu.com/ilpoe/docs

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3 Encouraging further application of the LiWa methodology

Having read this Transferability Manual up to here, the reader might now have got the impression that the adaptation and application of the methods and results of the LiWa project consists in a sheer insurmountable task, as so many recommendations have been given in the preceding chapters. However, preparing a city – or, more generally speaking, a region – to the challenges of the future, to make it more resilient under the overall goal of sustainability, is a path worthwhile to be stepped on. It is beneficial to recall that (as it was stated in Section 2.3.1) the future is uncertain and with regard to many fields not predictable.

Despite this uncertainty, decisions have to be taken today with regard to investment plans and long term strategies. The methods, results and recommendations given in this document will assist in developing robust plans and strategies for decision-making that consider future risks and potentials. The partners who have been involved in the LiWa project and who have authored the sections of this manual will be more than happy to assist you in developing the next steps for your city and region.