THE UNIVERSITY OF HONG KONG
Centre for Water Technology and Policy

Inter-disciplinary Forum

"Climate-resilient Urban Water Systems: New Technologies and Policy Challenges"

Report on Plenary Session 4: Planning and Management

Date: 29 May 2018
Time: 3:45 – 5:15 p.m.

Chaired by:
Professor Kaimin Shih
Department of Civil Engineering
The University of Hong Kong

"Participatory Systems Dynamics Modeling in Water Resources Planning and Management"
Professor Jan Franklin Adamowski
William Dawson Scholar, Department of Bioresource Engineering
McGill University

"Water PPPs in Asia: Trend and Prospect"
Professor Wu Xun
Director, Institute for Public Policy
The Hong Kong University of Science and Technology

“Participatory Systems Dynamics Modeling in Water Resources Planning and Management”

by Professor Jan Franklin Adamowski
William Dawson Scholar, Department of Bioresource Engineering, McGill University

Application of system thinking in water decision making

- In the context of transitioning to more climate resilient urban water systems, “Participatory Systems Dynamics Modeling” can be viewed as an approach to help:
  (1) facilitate productive discussions with key stakeholders;
  (2) develop & explore possible solutions, strategies with key stakeholders; and
  (3) promote an interdisciplinary approach to solving water problems.

The old and the new System Dynamic Modelling

- System Dynamics (SD) Modeling, developed in the 1950s, can facilitate understanding of the behavior of complex, non-linear systems that have a feedback loop.
- Instead of giving “precise” or predictive answers as conventional models do, SD provides insights into stakeholder perceptions of particular problems, like water scarcity, causes, consequences, & strategies and facilitate decision-making.
- SDM is used in different areas of policy decision making because of its benefits of showing and analyzing interrelations between environmental, economic & social aspects.
- Conventional SDMs cannot fully represent the dynamics of stakeholders but new SDM, combining stakeholder involvement, takes into account of stakeholders’ perception and complex socio-economic processes. The SDM also seeks to model the feedback processes and possible effects of different strategies/policies.
- The new SDM is a more accurate representation of participatory & integrated water management” policy dynamics. A more effective way of facilitating stakeholder discussion is therefore created.

Qualitative SDM/ Causal loop system

- In order to identify how belief system works among different stakeholders, mental maps were used to visualize stakeholders’ perception and their thinking about policy problem, causes, consequences, feedbacks, strategies.
- A mental map typically comprises primary causes, secondary causes, the main problem, first order consequences, secondary consequences and a feedback system.
- A range of stakeholders were included in the structuring of the loop system (e.g. local stakeholders, representative from different sectors like industry, agriculture, commerce, government officials at different levels, researchers and experts of different fields, NGOs and under-represented groups). Working with individuals, instead of small groups ensures voices from all stakeholder groups could be heard.
- The SDM was used in the Water & Food Security Project in Guatemala and water scarcity issues in Cyprus.

Quantitative SD Modeling/ Stock & Flow diagram or Simulation Models

- Quantitative model refers to the quantification and development of mathematical relationships between variables in system
- What a person thinks about a system, or their specific mental model of a system, can be captured by the qualitative model. Quantitative SD Modeling is built by the aggregation of mental models of different individuals. Such a model is also, in theory, closer representation of the reality.
- In our latest research, we have engaged stakeholders in watershed modeling, planning & management by use of the participatory model building framework.
- The participatory model becomes more sophisticated with investment of time and resources. It begins with problem framing, then stakeholder analysis, and then individual modelling. By consolidating results of individual modelling, we can then develop a group model, and finally a simulated scenario about institutionalized participation.
- Application: watershed management in Cyprus, Quebec, Guatemala, Ontario, Pakistan, Korea and Italy with different hydrological contexts, socio-economic situations, climatic conditions, land use characteristics and legislations.
- Research in participatory system dynamics modeling is still in its infancy stage. Application to many inter-disciplinary topics requires further research efforts.
- Questions to be addressed include how to ensure inclusion of traditionally under-represented stakeholders (e.g. First Nations in Canada) and ‘institutionalization’ of participatory modeling.

“Water PPPs in Asia: Trend and Prospect”

by Professor Wu Xun
Director, Institute for Public Policy,
The Hong Kong University of Science and Technology

Background

- Huge capital investments are required for provision of utilities and urban infrastructure in Asia. There are even higher capital investment requirements after taking into account of climate change risks.
- Neither the public nor the private sector alone can afford to build water infrastructure for all people.
- Limited capital input for building and maintaining government-owned water utilities in developing countries has resulted in a vicious cycle, which undermines long-term water sustainability. PPP is important to break this vicious cycle.
- There are also intense populist sentiments or negativity against private sector’s involvement in water sector.

PPPs in Water Sector in Asia & China (data from PPIAF)

- Overall trend: Significant volatility
- China contributed to the greatest number of PPPs
- When China is taken out from the picture, there is a decline in PPPs in other Asian countries in the last two decades.
- By examining the distribution of PPPs in three time periods (i.e. 1994-2000; 2001-2010; and 2011-2017) in China, it is evident that water utility was the major focus in the 1990s while sewage treatment and other environmental management projects are the mainstream options for PPPs after 2000. Cancelled project/ failure rate also peaked in 1990s (more than 1/3 of the projects were cancelled).

First wave of water PPPs in China

- In order to address water supply problems and to relieve financial burdens for water works construction, China began to deregulate the water sector in the 1990s and opened up the market to the private sector. Most projects were completed in partnership with private investors. The Urban Water Price Regulation enacted in 1998 allows local governments to set water tariffs to guarantee foreign investors a net return rate of 8–10%.
- Key government officials were also eager to secure PPP projects, because their career advancements were closely linked to the amount of foreign direct investment brought in.
- In 2002, the General Office of the State Council promulgated a specific circular to make the provision of fixed rate of return for foreign investors illegal. Consequently, terms and conditions of on-going contracts had to be modified or re-negotiated, thus contributing the high number of PPP project cancellation in early 2000s.

Second wave of water PPPs in China

- The measures introduced after 2002 resulted in a significant increase in water tariffs, which in turn contributed to the second wave of water PPPs in China. From 2001 to 2012, there were 237 water and sanitation PPPs in China, accounting for 40% of the total number of such projects globally.
- Even though the PRC government no longer guarantees returns, an increase in water tariffs makes PPP of water utilities a favorable option among foreign investors. Domestic investors also assumed a more significant role.

Institutional issues

- An absence of credible regulatory mechanisms, such as economic regulation to determine a fair tariff level, will undermine long-term prospects of PPPs in China.
- Public hearing, which is a primary mechanism for tariff review, is not effective at all.
- There is a strong bias favoring projects involving significant private sector investment, as the performance of key local government officials is often evaluated by their success in attracting such investments.

Lessons learnt

- First, water tariff reform (increase in water tariff) is a necessary condition for development of sound PPPs in the water and sanitation sector. In contrast, guaranteed returned is not necessary.
- Second, strong support and oversight from the national government is essential for the development of PPPs in the water and sanitation sector.
- Third, credible regulatory mechanisms must be in place for ensuring sustainability of PPPs in the water and sanitation sector.

Panel Discussion

Q1: What researchers could do to facilitate stakeholders' discussion and to develop a good model to capture their opinions?

Adamowski:

We found that in big group modelling session (with around 15-20 participants), certain stakeholders were not comfortable to express their opinions when other stakeholders were present. Some participants refrained from speaking up because government officials, who were funding their work, were there in the same session. We learnt that, in order to hear from each stakeholder, it is important to do the individual mind mapping exercise anonymously first. The group mapping exercise can be conducted at a later stage.

Q2: Are non-official, business-to-business PPPs captured in the Public-Private Infrastructure Advisory Facility (PPIAF) database? What is your view on informal or unregulated PPPs?

Wu:

The PPIAF dataset has its limitations. For instance, certain types of PPPs were not included. There are also definitional issues. Partnerships between local governments and SOEs/ government-owned utility companies were not considered as PPP under international definitions. However, they are counted as PPPs in the PPIAF database.

Q3: Are there any successful examples of PPP regulation by local governments?

Wu:

The UK government has regulated all utility companies. There are also successful examples in developing countries. PPP regulation is important for ensuring quality and success of PPPs. From our research, we found that an absence of regulations is not only a problem in China, but it's true in the other parts of the world. To address the problems that local governments are uninterested in regulatory works, it is important to have a regulatory body at the national or regional level. The international best practices show that well-functioning regulatory agencies are usually independent agencies that can ensure consumer interests are protected, as they are not affected by government agendas.

Q4: Can low income groups afford to pay for the increasing tariffs?

Wu:

The water tariffs in Asia and China are comparatively cheap. Even with an increase in water tariffs, the water tariff as a percentage of household income is fairly low. I think affordability is not an issue so far. Instead there is a more pressing need to invest in the water supply system and to break the vicious cycle of under-investment.

Q5: What makes wastewater treatment facility a popular PPP option in China?

Wu:

Treatment plants have more promising, secured financial returns. As a centralized facility, operators of wastewater treatment facilities need not to collect money from individual users. Tariffs paid by customers have a designated waste water treatment component, which can guarantee certain amount of return as well. New environmental challenges and threats, like water pollution, also increase government's attention on waste water treatment issues.

Participatory System Dynamics Modeling in Water Resources Planning & Management

Jan Franklin Adamowski, MBA, PhD, PEng

Associate Professor & William Dawson Scholar, Department of Bioresource Engineering
Liliane and David M. Stewart Scholar in Water Resources
Director, Integrated Water Management Program
Interim Director, Brace Centre for Water Resources Management

McGill University

In the context of transitioning to more climate resilient urban water systems

Participatory Systems Dynamics Modeling can be viewed as an approach to help:

1. *Facilitate* productive discussions with key stakeholders.

2. *Develop* & *explore* possible solutions with key stakeholders.

3. *Promote* an interdisciplinary analysis of the problem.

OUTLINE OF TODAY'S TALK

1. System Dynamics (SD) Modeling Background.

2. Participatory Model Building Framework.

System Dynamics (SD) Modeling

Background

System Dynamics Modeling

System dynamics (SD) developed in 1950s by Jay Forrester at MIT.

SD can help to understand the behavior of complex systems over time.

SD *different* from other approaches to studying complex systems due to:

use of *feedback loops* which help describe how even simple systems can be 'complex' & *nonlinear*.

	AI / Physically Based Modeling (e.g., ANNs, SWAT, HEC-HMS, etc.)	Participatory System Dynamics Modeling
Main Uses	Provide ‘precise’ answers.	Does not provide ‘precise’ answers. Provides insights into: Stakeholder perceptions of problems, causes, consequences, & strategies. Feedback loops. General trends. Facilitate discussions. Etc.

SYSTEM DYNAMICS MODELING (SDM)

SDM allows for:

Integrated analysis of problems (i.e., the interrelations between environmental, economic & social aspects can be analyzed).

System dynamics modeling has been used in water resources management.

However, to date most SDM studies:

1. Do not really incorporate stakeholders in development & use of models.
2. Those that include stakeholders tend to develop very simplified models (e.g., limited integration of both physical & social components).

Why use System Dynamics Modeling
combined with
Stakeholder Involvement?

- Incorporate key stakeholders (e.g. experts, implementers, decision makers, users, etc.) in development & use of models
    - Better design, implementation + ethical considerations
    - Explore stakeholder perceptions (mental maps).
    - Facilitate productive stakeholder discussions.

- Integrate physical & socio-economic processes important in WRM.

- Explore feedback processes in system.

- Model effects of strategies/policies (e.g. explore unexpected outcomes)

  e.g. - policies to increase resilience of urban water systems

  - demand management, adaptive management, etc..

Help operationalize the concepts of "participatory & integrated water management"

TWO TYPES
OF
SYSTEM DYNAMICS MODELING

1. Causal loop diagrams:

- Qualitative SD modeling

2. Stock-and-flow diagrams / SD simulation models:

- Quantitative SD modeling

1. Causal Loop Diagrams

Qualitative SD Modeling

Qualitative SDM -
Causal Loop Diagram

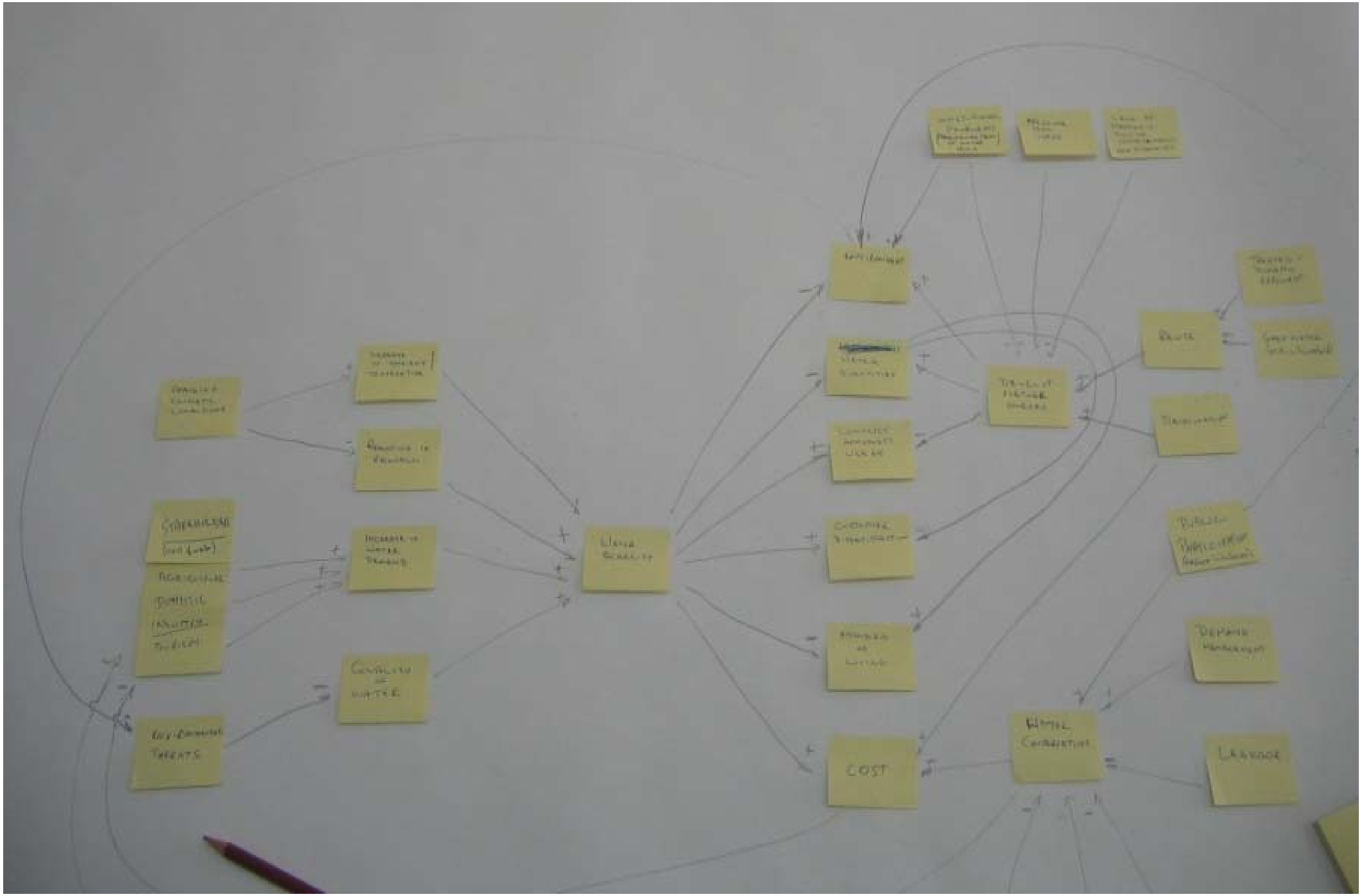
Mental map representing what is important to a stakeholder about a management issue:

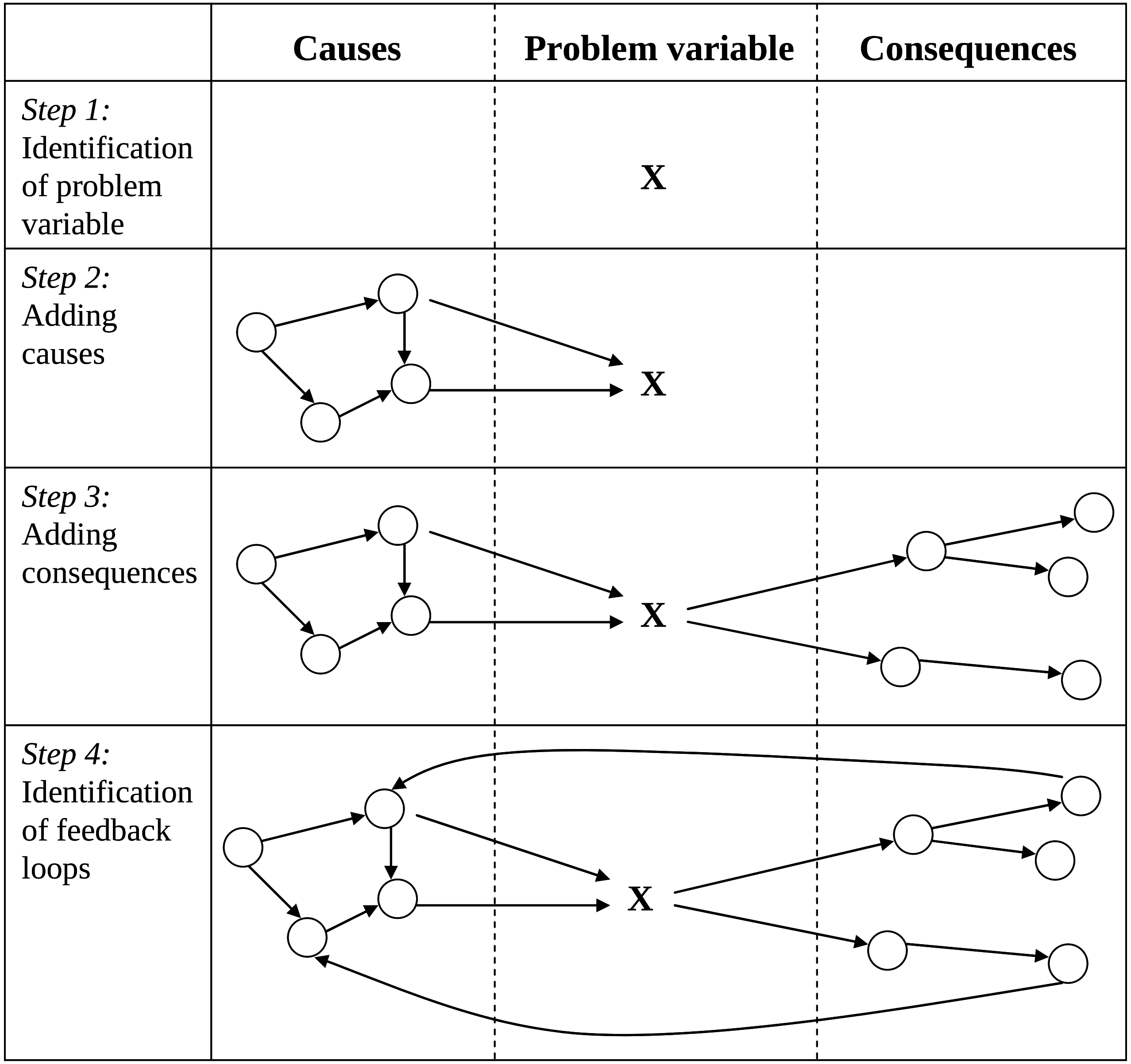
- Important elements of system
- Their relationships to one another
- Problem, causes, consequences, feedbacks, strategies.

Can identify:

1. Beliefs about how system works
2. Problems & solutions

Example of Qualitative SDM: Water scarcity in Cyprus





X = problem variable
= other variables

(Vennix, 1996)

"Causal Loop Diagrams"
Qualitative System Dynamics Models

Must identify key stakeholders (many approaches e.g., *Inam et al. 2015*)

Must ensure diverse representation

- local stakeholders (e.g., farmers, …)
- sectors: industry, agriculture, commerce, ….
- government (municipal, provincial, federal)
- 'experts' (water, agriculture, social issues, modelers, academics)
- NGOs
- Traditionally under-represented stakeholders (e.g. First Nations in Canada)
- Etc…

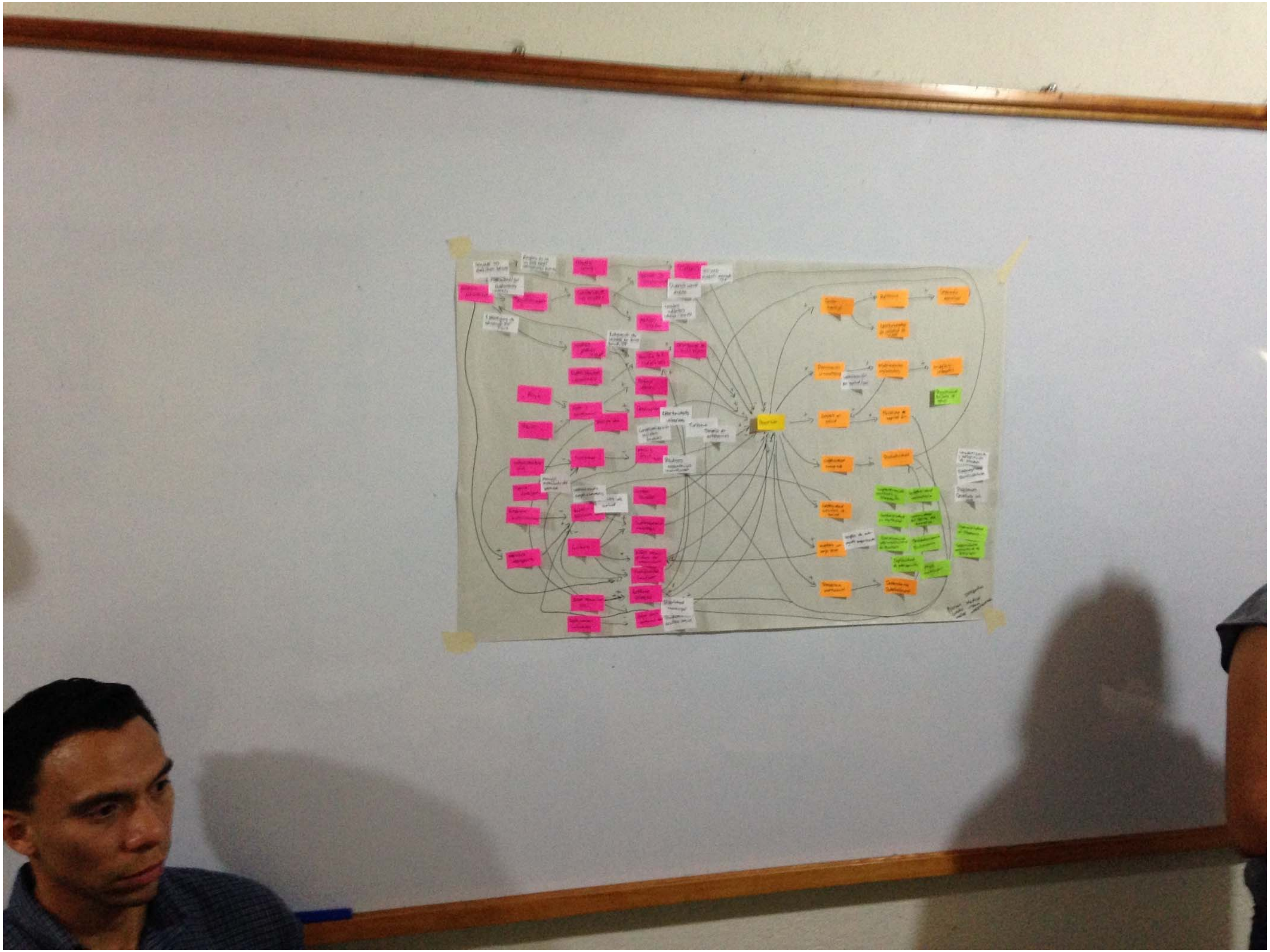
Pictures from CLD process

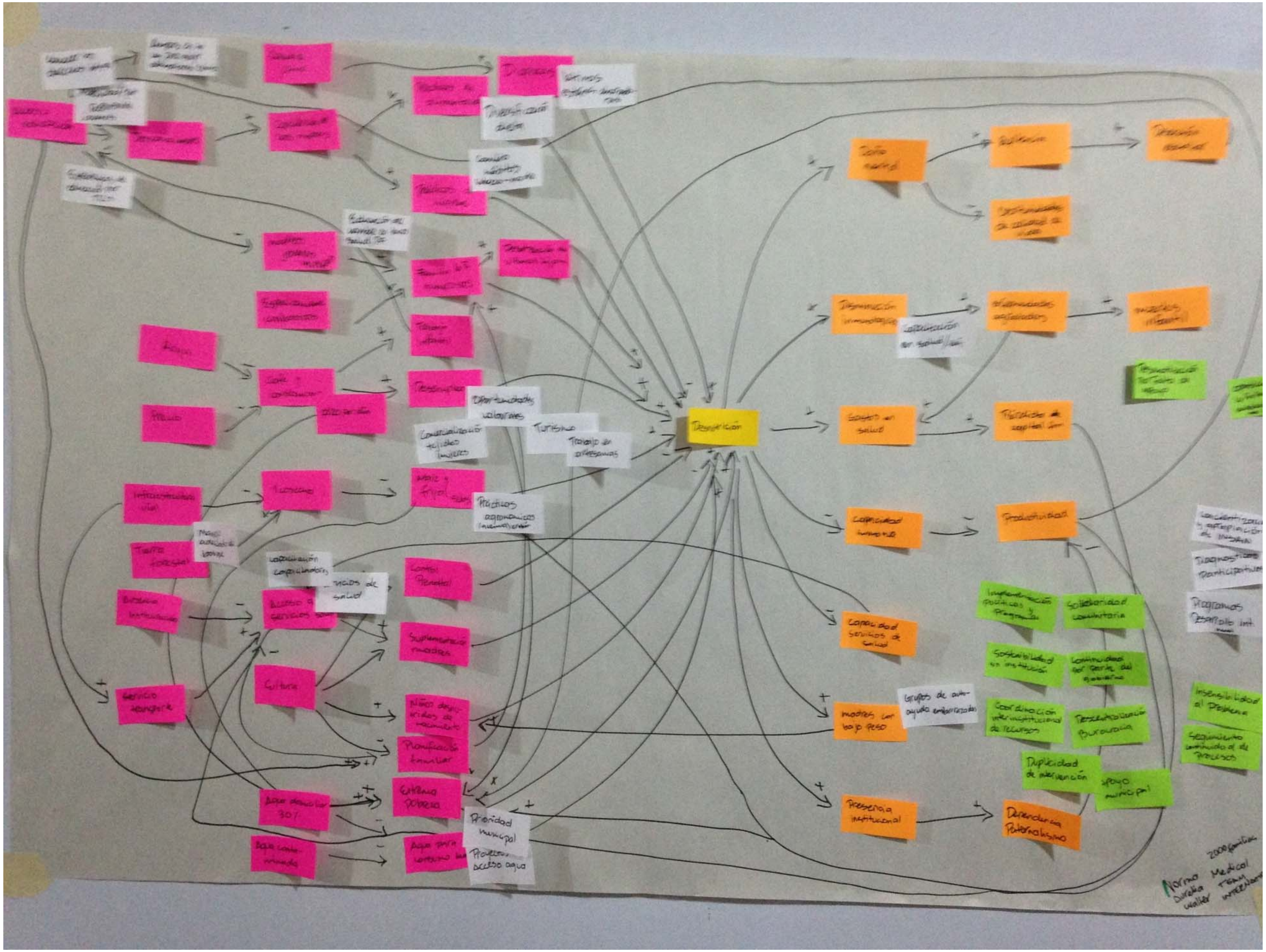
in a

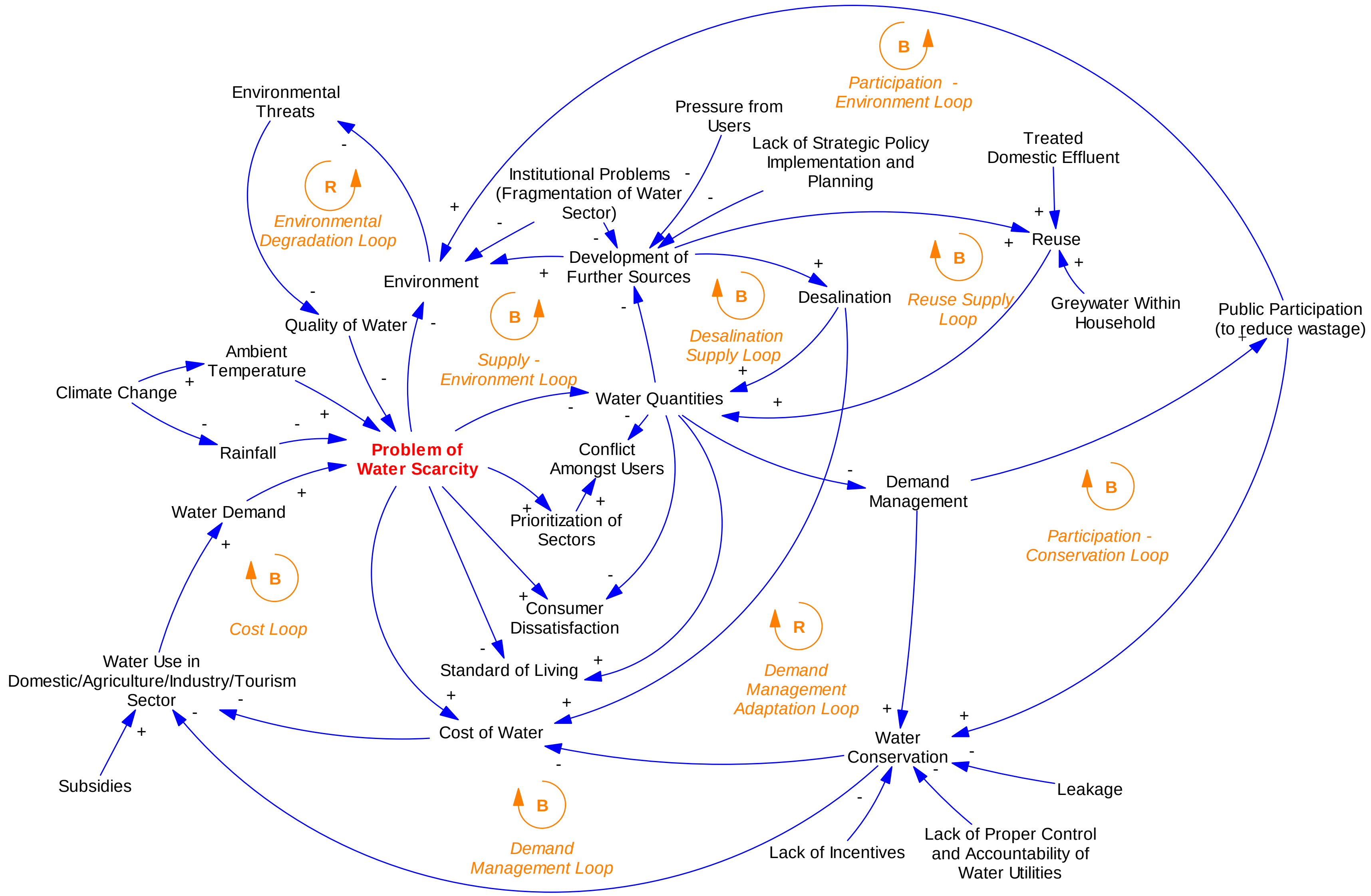
Water & Food Security Project

in

Guatemala




Diarreas
Diversificación dietas
Desnutrición
Oportunidades laborales
Turismo
Trabajo de artesanías
Prácticas agronómicas
Control Prenatal
Acceso a servicios de salud
Cultura
Planificación familiar
Extrema pobreza
Agua potable 30%
Prioridad municipal
Proyectos acceso agua
Gasto en salud
Productividad
Capacidad servicios de salud
madres con bajo peso
Grupos de auto-ayuda embarazadas
Presencia institucional
Dependencia Paternalismo
Solidaridad comunitaria
Coordinación interinstitucional de recursos
Duplicidad de intervención
Apoyo municipal
Insensibilidad al Problema
Seguimiento continuado de procesos
Programas Desarrollo Int
Diagnóstico Participativo



Example of a Qualitative SDM developed by 1 stakeholder after a

<u>1-hour model building session</u>

2. Stock & Flow / Simulation Models

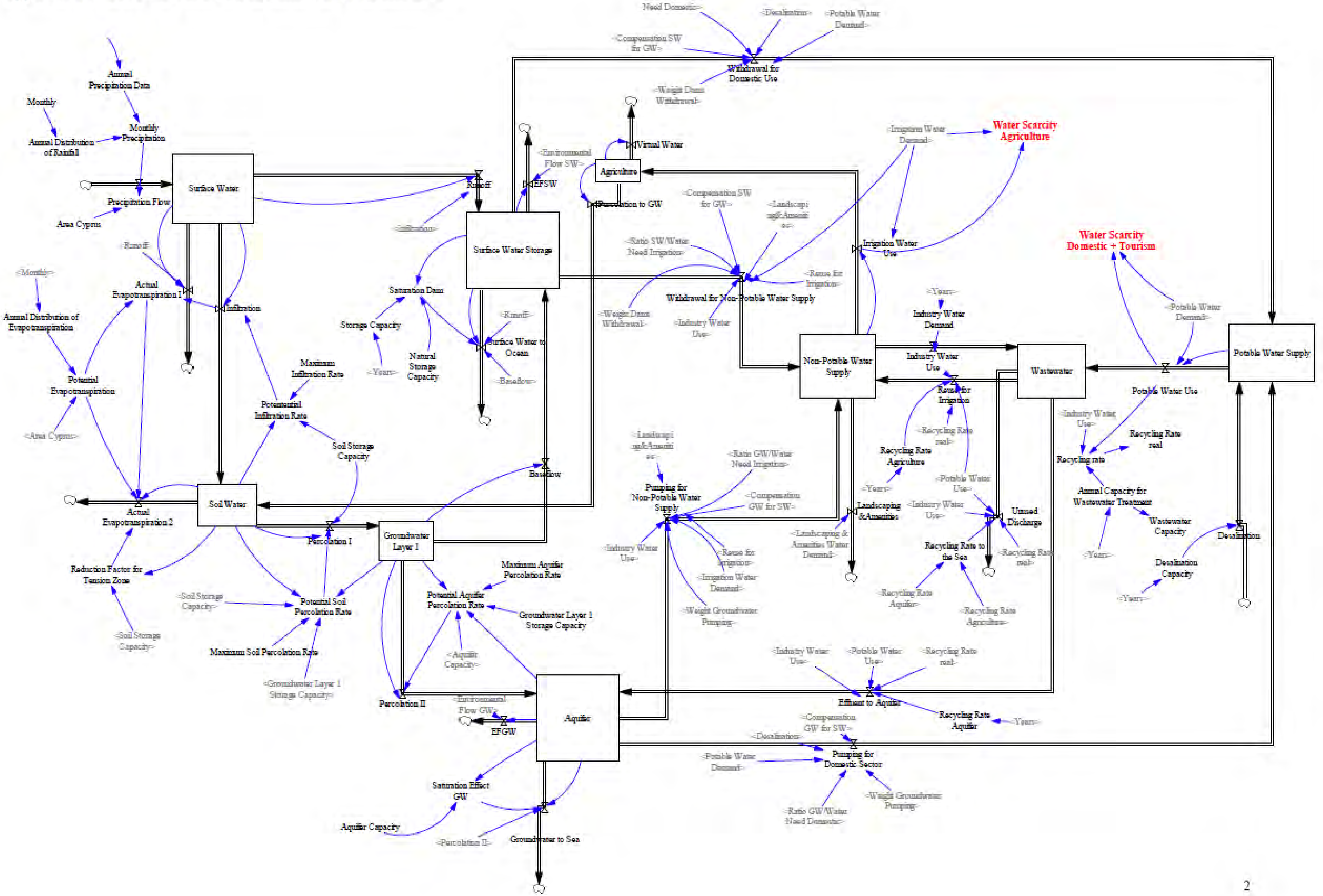
Quantitative SD Modeling

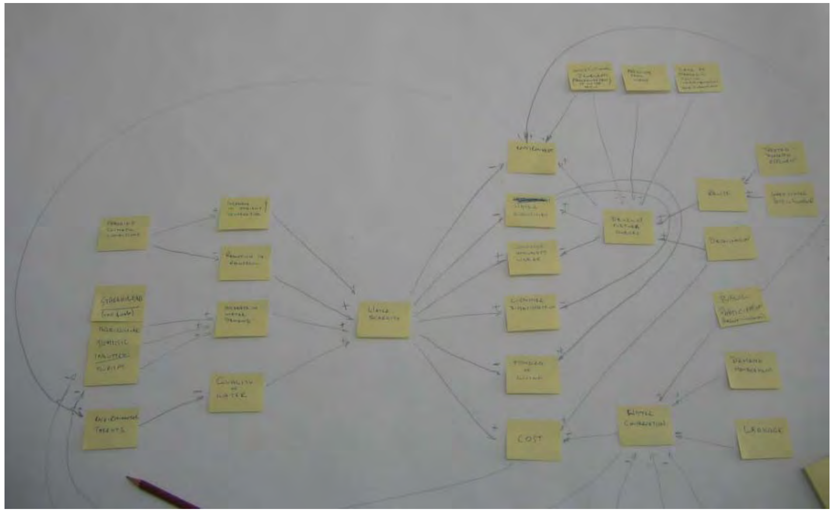
Using a stakeholder built qualitative SD model (CLD)
can
develop *mathematical relationships* between variables in system
to
quantify CLD.

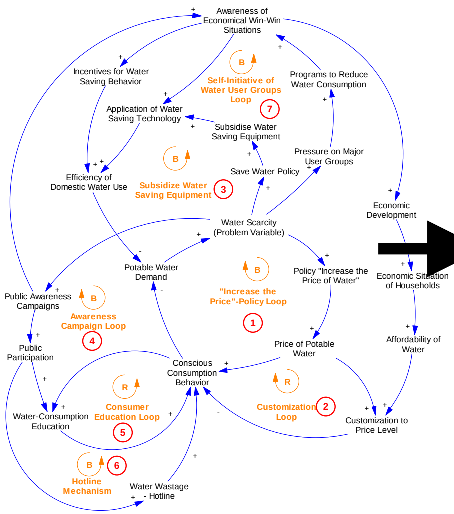
Becomes a *simulation* model

Example of a ***Quantified CLD***

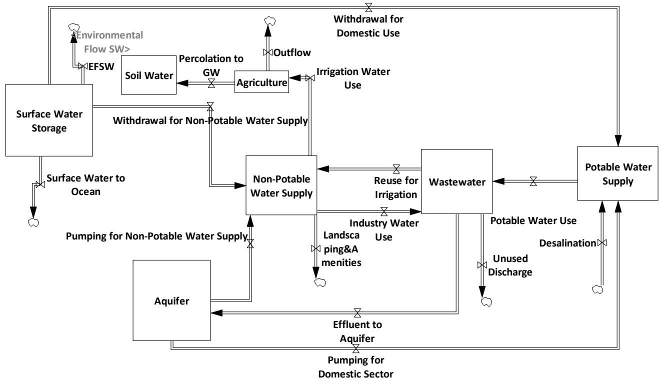
Appendix F1: Stock and flow structure of the hydrological and allocation model



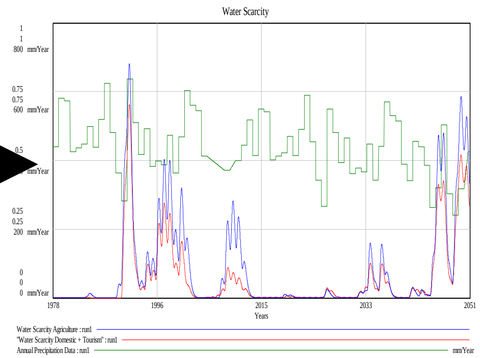




Awareness of Economical Win-Win Situations
Incentives for Water Saving Behavior
Self-Initiative of Water User Groups Loop
7
Programs to Reduce Water Consumption
Application of Water Saving Technology
Subsidise Water Saving Equipment
Pressure on Major User Groups
Efficiency of Domestic Water Use
Subsidize Water Saving Equipment
3
Save Water Policy
Economic Development
Water Scarcity (Problem Variable)
Potable Water Demand
Policy "Increase the Price of Water"
Economic Situation of Households
"Increase the Price"-Policy Loop
1
Public Awareness Campaigns
Awareness Campaign Loop
4
Public Participation
Price of Potable Water
Affordability of Water
Conscious Consumption Behavior
Consumer Education Loop
5
Customization Loop
2
Water-Consumption Education
Customization to Price Level
Hotline Mechanism
6
Water Wastage - Hotline



Withdrawal for Domestic Use
Environmental Flow SW>
EFSW
Outflow
Percolation to GW
Soil Water
Agriculture
Irrigation Water Use
Surface Water Storage
Withdrawal for Non-Potable Water Supply
Surface Water to Ocean
Non-Potable Water Supply
Reuse for Irrigation
Wastewater
Potable Water Supply
Industry Water Use
Landsca ping&A menities
Potable Water Use
Pumping for Non-Potable Water Supply
Unused Discharge
Desalination
Aquifer
Effluent to Aquifer
Pumping for Domestic Sector



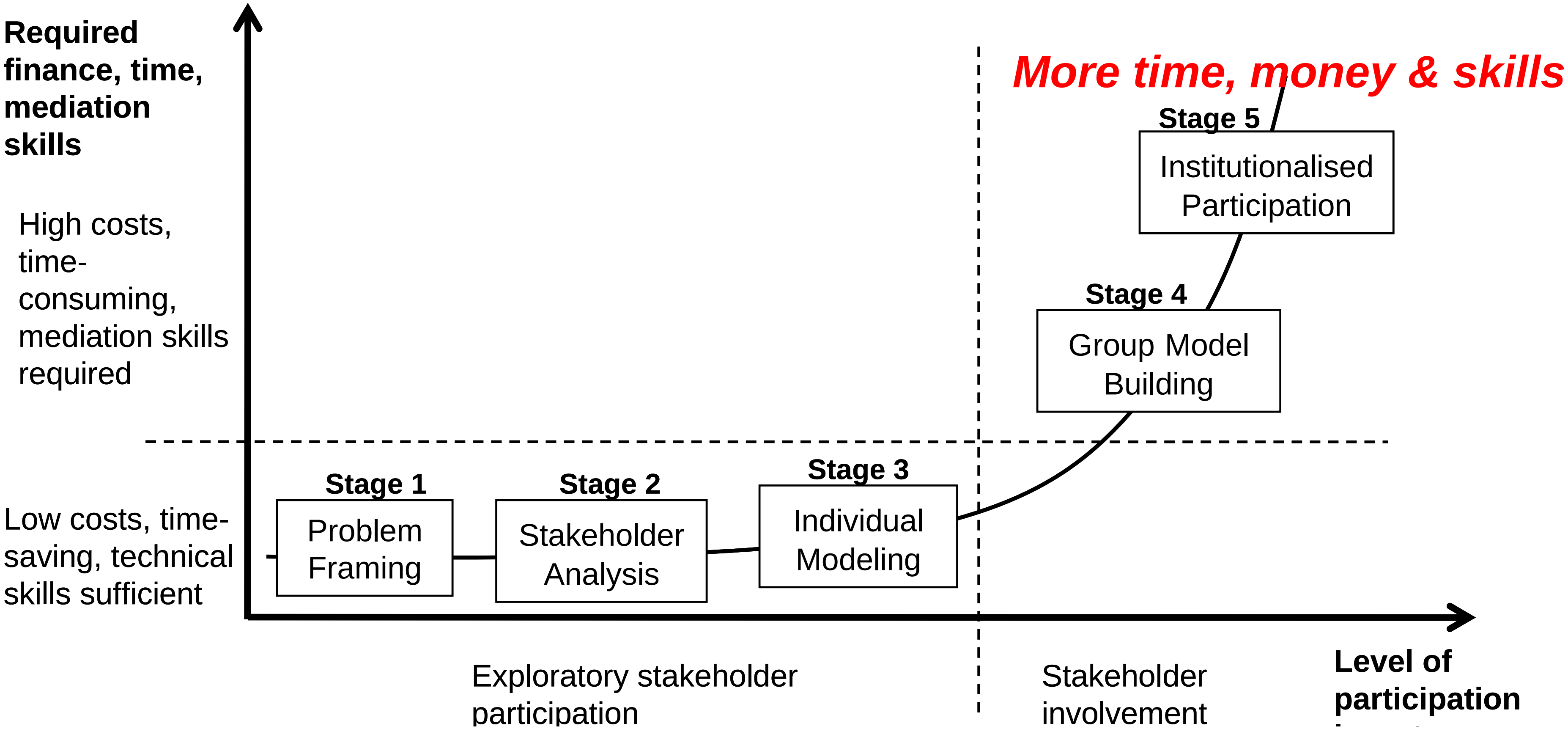
Water Scarcity
Years
Water Scarcity Agriculture : run1
"Water Scarcity Domestic + Tourism" : run1
Annual Precipitation Data : run1

Current Series of Research Projects:

Engaging Stakeholders
in
Watershed Modeling, Planning & Management
via the

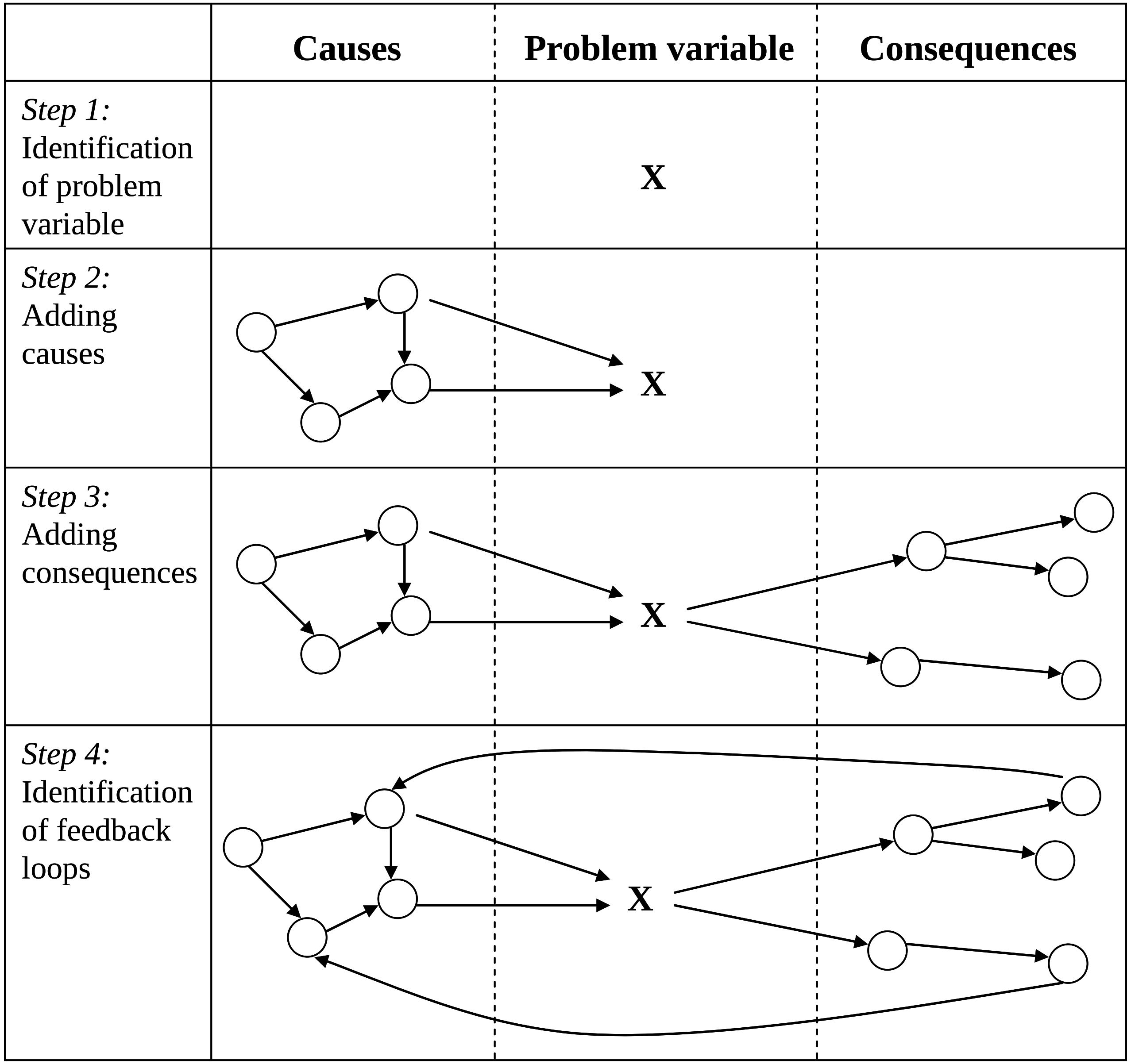
Participatory Model Building Framework

PARTICIPATORY MODEL BUILDING FRAMEWORK



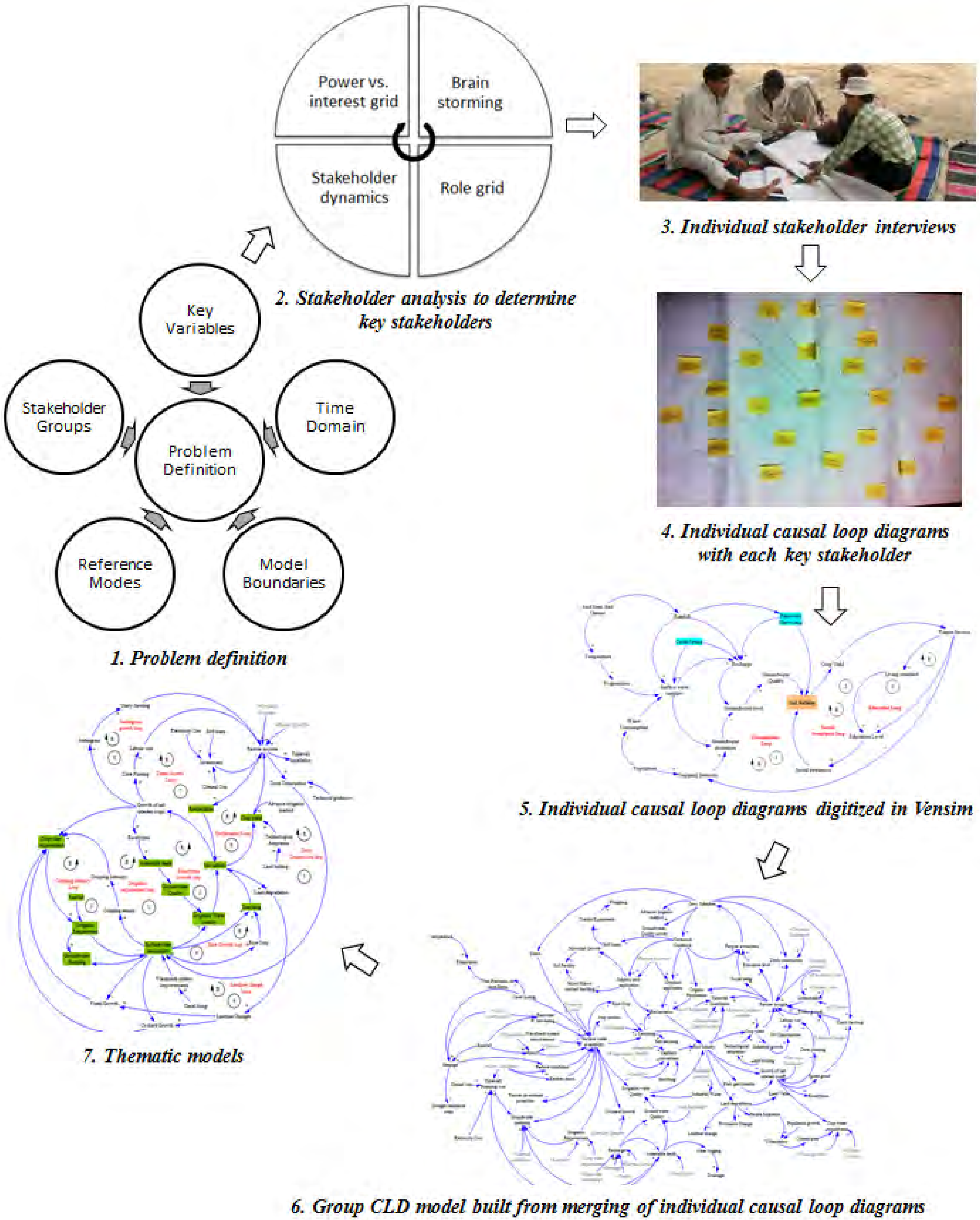
A stepwise approach towards participatory model building

(Inam, Adamowski, Halbe, Prasher
Journal of Environmental Management 2015)



X = problem variable
○ = other variables

(Vennix, 1996)


Power vs. interest grid
Brain storming
Stakeholder dynamics
Role grid
2. Stakeholder analysis to determine key stakeholders
3. Individual stakeholder interviews
4. Individual causal loop diagrams with each key stakeholder
5. Individual causal loop diagrams digitized in Vensim
6. Group CLD model built from merging of individual causal loop diagrams
7. Thematic models
Key Variables
Stakeholder Groups
Time Domain
Problem Definition
Reference Modes
Model Boundaries
1. Problem definition

Participatory SD Model

1. Includes stakeholder's 'mental maps' related to a problem (i.e., causes, consequences, feedbacks, solutions, etc.).

2. Combines local & expert knowledge to analyze policies in a participatory & integrated manner.

3. Can facilitate meaningful stakeholder discussions.

Note: Not intended to be used for forecasting, etc.

CURRENT STUDY AREAS

Research is being conducted in several selected watersheds in:

1. Cyprus
2. Quebec
3. Guatemala
4. Ontario
5. Pakistan
6. Korea
7. Italy

With different:

Hydrological contexts
Socio-economic situations
Climates
Land use characteristics
Legislation
Etc.

Examples of Papers we have Published on this Topic

Using causal loop diagrams for the initialization of stakeholder engagement in soil salinity management in agricultural watersheds in developing countries: A case study in the Rechna Doab watershed, Pakistan. *Journal of Environmental Management*.

A small-scale socio-hydrological model to understand the dynamics in a watershed that reuses wastewater for paddy irrigation in South Korea. *Journal of Agricultural Water Management*.

Application of process mapping and causal loop diagramming to enhance engagement in pollution prevention in small to medium size enterprises: case study of a dairy processing facility. *Journal of Cleaner Production*.

Use of participatory system dynamics modelling to assess the sustainability of smallholder agriculture. *American Society of Agricultural and Biological Engineers Annual International Meeting.*

Coupling of a distributed stakeholder-built system dynamics socio-economic model with SAHYSMOD for sustainable soil salinity management. Part 1: Model development. *Journal of Hydrology.*

Coupling of a distributed stakeholder-built system dynamics socio-economic model with SAHYSMOD for sustainable soil salinity management. Part 2: Model coupling and application. *Journal of Hydrology.*

Parameter estimation and uncertainty analysis of SAHYSMOD in the semi-arid climate of Rechna Doab, Pakistan. *Journal of Environmental Modeling and Software.*

CONCLUSION

Research in participatory system dynamics modeling is in its infancy.

Many inter-disciplinary topics to still explore:

- Model coupling (P-SDM + Physically Based Models)
- Inclusion of traditionally under-represented stakeholders (e.g. First Nations in Canada)
- Long term ‘institutionalization’ of participatory modeling
- Etc.

THANK YOU!

Stage 1: Preliminary Problem Framing

Water scarcity identified as the problem variable

Does the problem definition justify the application of participatory methods?

Yes, because water scarcity is:

1. An urgent problem

2. Causes conflicts between users

3. Depends on user cooperation for the reduction of water demand

Therefore problem definition motivates multiple stakeholders like water users, decision makers, & legislative bodies.

Stage 2: Stakeholder Analysis

Step 1: 'Stakeholder map' developed in brainstorming session with local experts & stakeholders.

Step 2: Detected stakeholders sorted into categories based on their functions in water management process (& gaps examined).

Step 3: Power vs Interest Grid created.

Step 4: Stakeholders assigned into latent, expectant or definitive groups, & variations in group's composition anticipated.

Additional Slides
on
Model Coupling

Stage 4:

1. Quantify Group SD Model

- Relationships between different variables defined via mathematical equations.

- Input into VENSIM through equation editor window.

- Built-in VENSIM functions can also be used to capture complex dynamics involved in system operations.

Stage 4:

1. Quantify Group SD Model

- Linear: irr req = crop water req – P

- NL: surface water availability = f(irr system eff, P, rainwater harvesting, earthen dam construction, waste water treatment)

- Socio-economic data: e.g.: awareness of farmers re sust irr practices (use index 0 to1).

  During model simulation, model checks index of people awareness
  Assigns values of irr eff according to it.
  Irr eff keeps changing as awareness changes
  Represents dynamic behavior of the system.

Stage 4:

2. Couple **SD Group Model with a Physical Model**

Prodanovic & Simonovic approach:

- "Component models" that render outputs of SD model compatible as an input to a physical model (e.g. HEC-HMS, SWAT), and vice versa.

- Involves changing source code of both models (i.e., SD & HEC HMS model) via a common programming language (i.e., Java).

Stage 4: Coupling approaches to be explored

1. EU HarmonIT project approach

Open Modeling Interface (OpenMI) developed to easily couple models with no programming skills.

Allows for simultaneous running of coupled physical and SD models by providing a standard interface for data exchange.

Models can be coupled that:

- Come from different suppliers
- Represent processes from different domains
- Are based on different concepts
- Have different spatial & temporal resolutions
- Have different spatial representations including no spatial representation

Stage 4: Coupling approaches to be explored

2. ‘Data exchange’

MS-Excel or dbase used as data exchange platform.

Data from SD model + physical model imported into database & exchanged at appropriate time step with the help of macros.

Process:

SD model initially simulates for one time step with some initial value of the physical variables.

At end of simulation data imported into data base & macro runs to update input file of the physical model.

A second macro runs physical model for one time step & imports simulated data into dbase.

A third macro updates *initial value of physical variables* in SD model & runs it for a second time step.

This process continues until end of simulation is reached.

Stage 4: **Coupling approaches to be explored**

2. 'Data exchange'

Process:

SD model can be paused & run at appropriate time steps through the gaming tool available in the DSS version of VENSIM.

Time step of physical model is controlled by specifying its time step to one period only.

Stage 4: **Coupling approaches to be explored**

3. Convert physical model into SD model

Convert physical model into SD model (or parts of).

Stage 4: Coupling approaches to be explored

Validation/testing of coupled model:

Coupled model assessed for correctness by comparing trends of simulated results with trends of reference modes developed from the previously observed sets of data.

Upon satisfactory results, model validated/tested with a *new data set* and finally tested for policy analysis.

Public-Private Partnerships in Water Sector in Asia

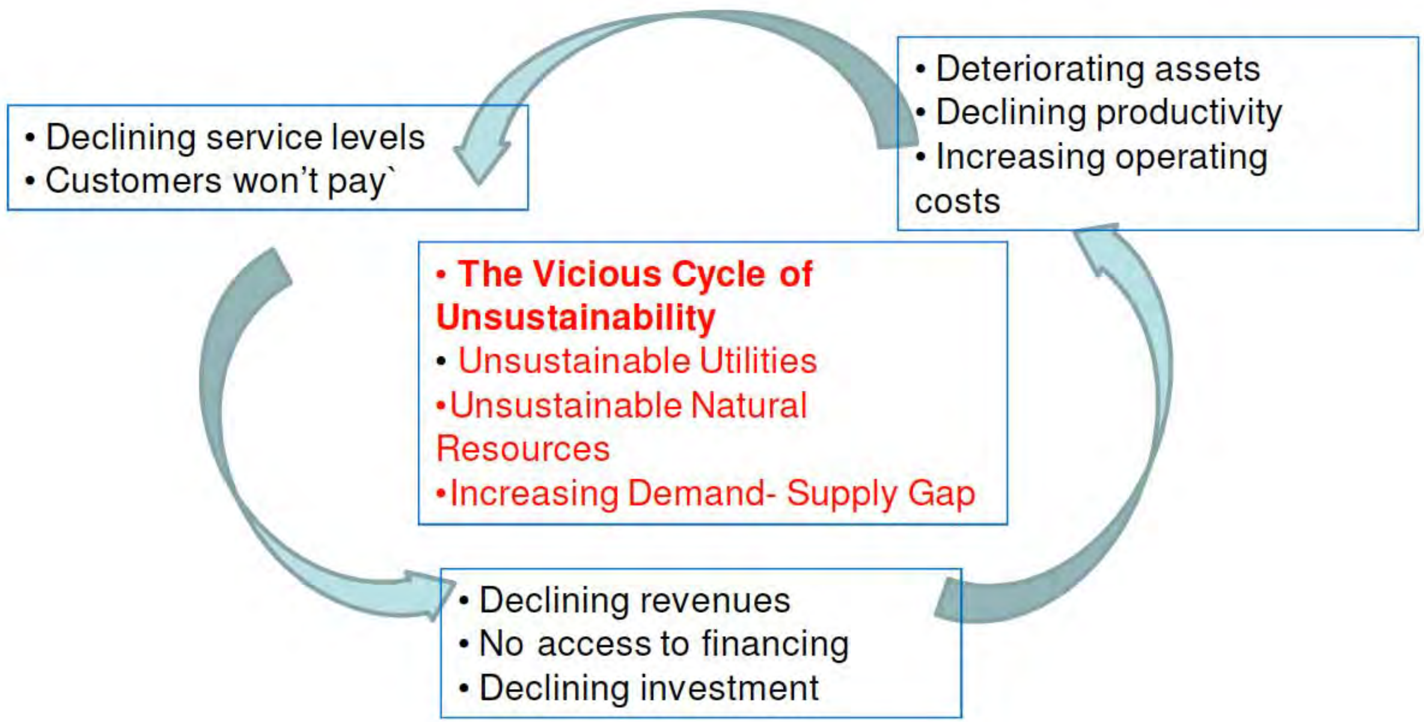
Xun Wu
Division of Public Policy
Hong Kong University of Science and Technology

Table 2: Estimated Infrastructure Investment Needs by Sector, 45 DMCs, 2016–2030
($ billion in 2015 prices)

Sector	Baseline Estimates			Climate-adjusted Estimates			Climate-related Investments (Annual)	
	Investment Needs	Annual Average	Share of Total	Investment Needs	Annual Average	Share of Total	Adaptation	Mitigation
Power	11,689	779	51.8	14,731	982	56.3	3	200
Transport	7,796	520	34.6	8,353	557	31.9	37	–
Telecommunications	2,279	152	10.1	2,279	152	8.7	–	–
Water and Sanitation	787	52	3.5	802	53	3.1	1	–
Total	**22,551**	**1,503**	**100.0**	**26,166**	**1,744**	**100.0**	**41**	**200**

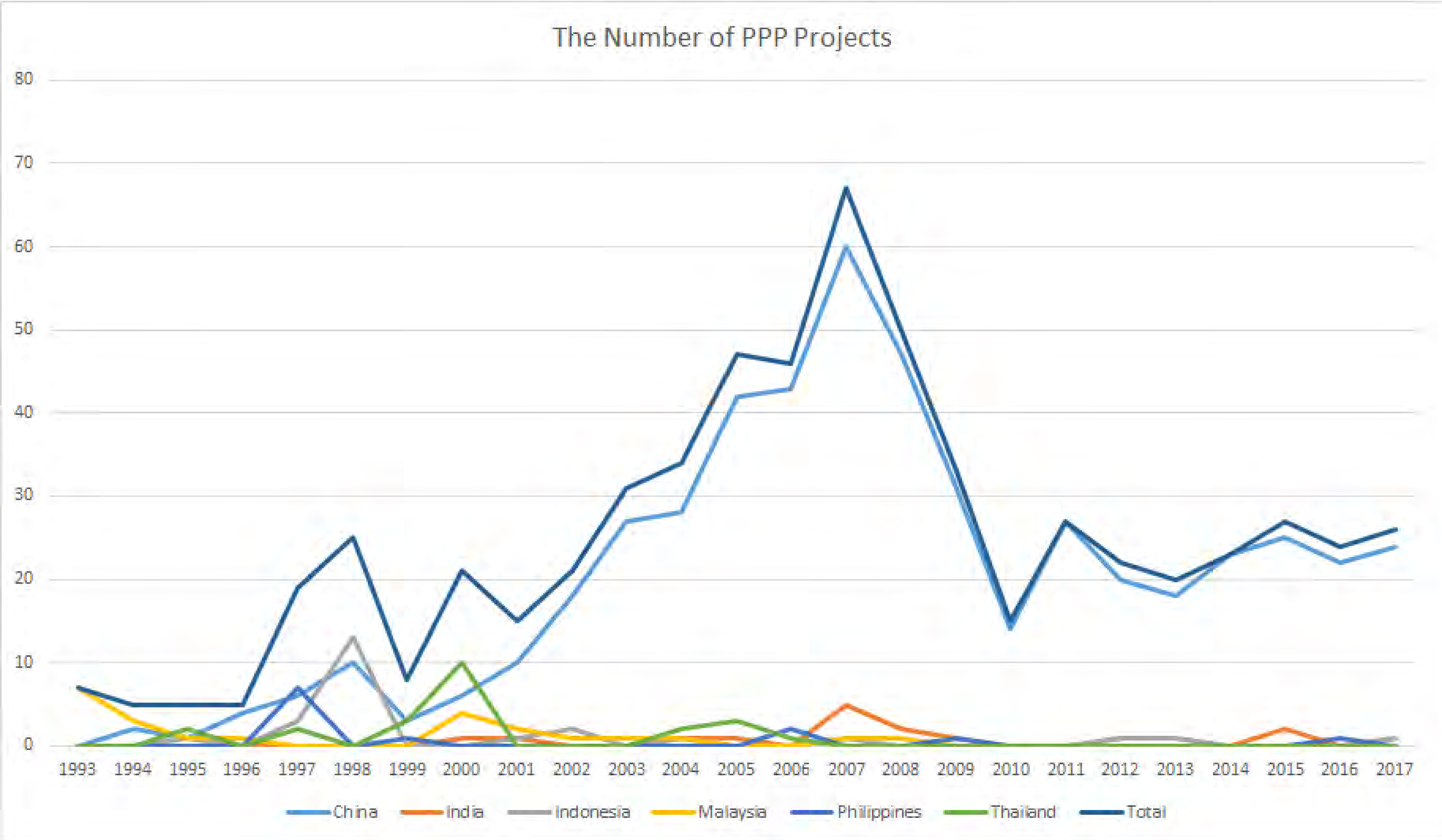
Note: – denotes not applicable.
Source: ADB estimates.

The Vicious Cycle Facing Government Owned Water Utilities in Many Developing Countries

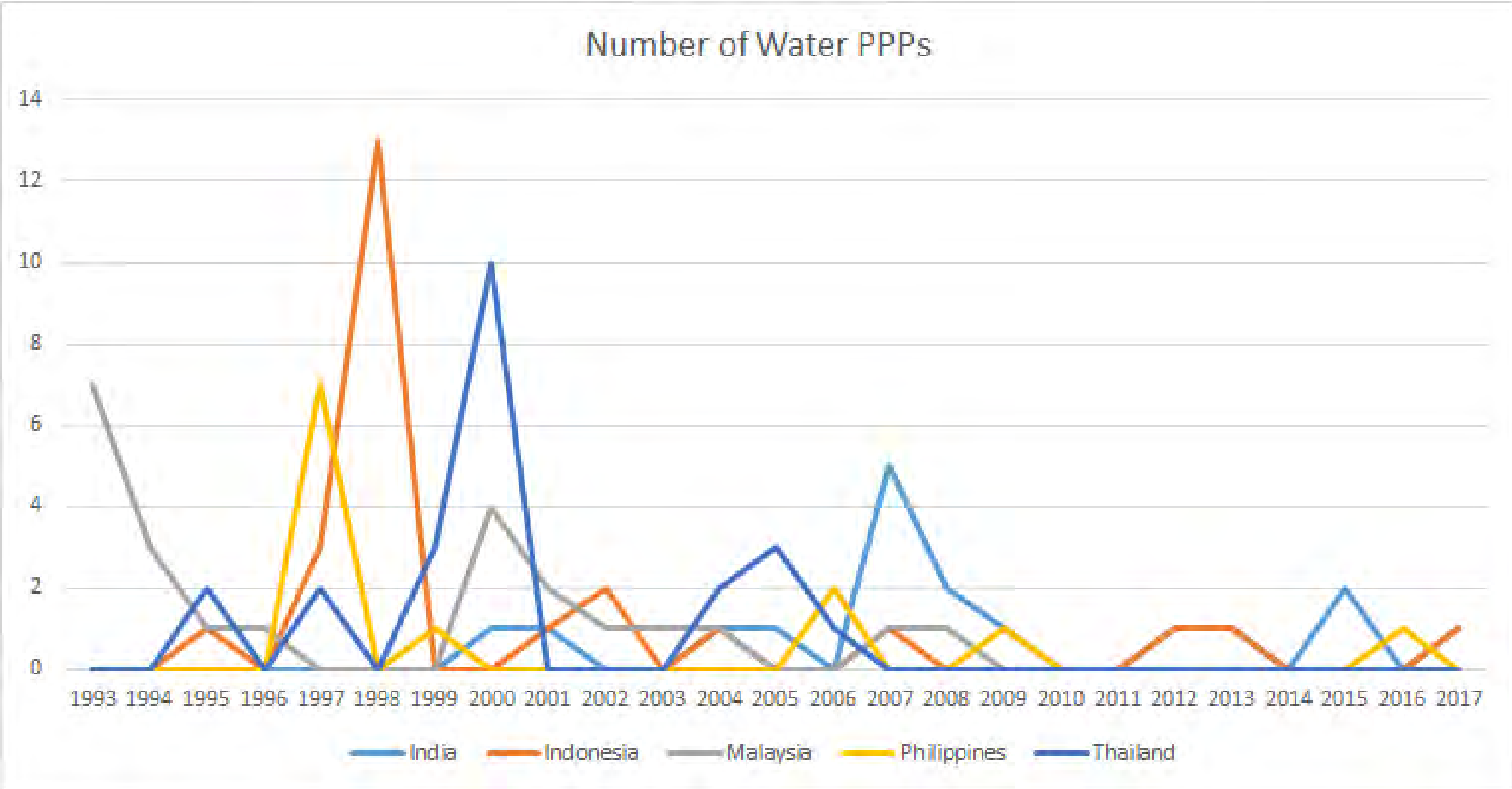


Populist Sentiment Against Private Sector Involvement in Water Sector

PPPs in Water Sector in Asia



PPPs in Water Sector in Southeast Asia and South Asia



Evolution of PPPs in the Water and Sanitation in Asia: 1993-2017

Number of Projects	Number of Projects			Percentage of Total Projects		
	1994--2000	2001--2010	2011--2017	1994--2000	2001--2010	2011--2017
PPP Type						
Concession	59	109	36	62.1%	30.4%	21.3%
Divestiture	4	11	2	4.2%	3.1%	1.2%
Greenfield	28	221	97	29.5%	61.6%	57.4%
Management and lease	4	18	34	4.2%	5.0%	20.1%
Total	95	359	169			
Project type						
Treatment plant	50	302	160	52.6%	84.1%	94.7%
Potable water and sewerage treatment plant	3	8	2	3.2%	2.2%	1.2%
Potable water treatment plant	46	68	8	48.4%	18.9%	4.7%
Sewerage treatment plant	1	226	150	1.1%	63.0%	88.8%
Water Utility	45	57	8	47.4%	15.9%	4.7%
Water utility with sewerage	9	17	3	9.5%	4.7%	1.8%
Water utility without sewerage	32	37	4	33.7%	10.3%	2.4%
Sewerage collection	0	1	0	0.0%	0.3%	0.0%
Sewerage collection and treatment	4	2	1	4.2%	0.6%	0.6%
Project Status						
Active	68	345	169	71.6%	96.1%	100.0%
Cancelled	22	5	0	23.2%	1.4%	0.0%
Concluded	2	3	0	2.1%	0.8%	0.0%
Distressed	3	6	0	3.2%	1.7%	0.0%

Evolution of PPPs in the Water and Sanitation in China: 1993-2017

Number of Projects	**Number of Projects**			**Percentage of Total Projects**		
	1994--2000	2001--2010	2011--2017	1994--2000	2001--2010	2011--2017
PPP Type						
Concession	16	89	33	50.0%	27.8%	20.8%
Divestiture	1	10	2	3.1%	3.1%	1.3%
Greenfield	15	211	90	46.9%	65.9%	56.6%
Management and lease	0	10	34	0.0%	3.1%	21.4%
Total	32	320	159			
Project type						
Treatment plant	30	286	153	93.8%	89.4%	96.2%
Potable water and sewerage treatment plant	2	7	2	6.3%	2.2%	1.3%
Potable water treatment plant	27	55	3	84.4%	17.2%	1.9%
Sewerage treatment plant	1	224	148	3.1%	70.0%	93.1%
Water Utility	2	34	5	6.3%	10.6%	3.1%
Water utility with sewerage	0	8	3	0.0%	2.5%	1.9%
Water utility without sewerage	2	23	1	6.3%	7.2%	0.6%
Sewerage collection	0	1	0	0.0%	0.3%	0.0%
Sewerage collection and treatment	0	2	1	0.0%	0.6%	0.6%
Project Status						
Active	20	315	159	62.5%	98.4%	100.0%
Cancelled	12	4	0	37.5%	1.3%	0.0%
Concluded	0	1	0	0.0%	0.3%	0.0%
Distressed	0	0	0	0.0%	0.0%	0.0%

Evolution of PPPs in the Water and Sanitation in the Rest of Asia:1993-2017

Number of Projects	Number of Projects			Percentage of Total Projects		
	1994--2000	2001--2010	2011--2017	1994--2000	2001--2010	2011--2017
PPP Type						
Concession	43	20	3	68.3%	51.3%	30.0%
Divestiture	3	1	0	4.8%	2.6%	0.0%
Greenfield	13	10	7	20.6%	25.6%	70.0%
Management and lease	4	8	0	6.3%	20.5%	0.0%
Total	63	39	10			
Project type						
Treatment plant	20	16	7	31.7%	41.0%	70.0%
Potable water and sewerage treatment plant	1	1	0	1.6%	2.6%	0.0%
Potable water treatment plant	19	13	5	30.2%	33.3%	50.0%
Sewerage treatment plant	0	2	2	0.0%	5.1%	20.0%
Water Utility	43	23	3	68.3%	59.0%	30.0%
Water utility with sewerage	9	9	0	14.3%	23.1%	0.0%
Water utility without sewerage	30	14	3	47.6%	35.9%	30.0%
Sewerage collection	4	0	0	6.3%	0.0%	0.0%
Sewerage collection and treatment	0	0	0	0.0%	0.0%	0.0%
Project Status						
Active	48	30	10	76.2%	76.9%	100.0%
Cancelled	10	1	0	15.9%	2.6%	0.0%
Concluded	2	2	0	3.2%	5.1%	0.0%
Distressed	3	6	0	4.8%	15.4%	0.0%

First Wave of water PPPs in China

- In order to address these problems and mainly fill the financial gap in the huge demand for water works, China began to deregulate the water sector in the 1990s and opened up the market to the private sector.
- One scheme was the twenty-first Century Urban Water Management Pilot Scheme in 1997, under which water tariffs were liberalized for projects with foreign capital and allowed foreign investors to receive desirable rates of return for water projects.
- Another key measure was the promulgation of the Urban Water Price Regulation in 1998 which allows the local governments to set water tariffs to guarantee foreign investors net return rate of 8–10%.

A Major Setback in 2002

- It was argued that preferable terms for foreigners are unfair for Chinese competitors.
  - Key government officials were eager to secure PPP projects, because their career advancement were closely linked with the amount of foreign direct investment brought in.
  - Many of contracts signed at the time were perceived as too lucrative for foreign investors as water users were asked to pay higher tariffs.
- In 2002, the General Office of the State Council promulgated a specific circular to make the provision of fixed rate of return for foreign investors illegal, and terms and conditions of on-going contracts had to be modified.

Changes in Average Water Tariff in Major Cities in China, 2000-2012

	2000		2012	
	RMB/m3	USD/m3	RMB/m3	USD/m3
Tianjin	1.60	$ 0.26	4.90	$ 0.80
Beijing	1.40	$ 0.23	4.00	$ 0.65
Shijiazhuang	1.10	$ 0.18	3.63	$ 0.59
Chongqing	1.02	$ 0.17	3.50	$ 0.57
Kunming	0.85	$ 0.14	3.45	$ 0.56
Haerbing	1.30	$ 0.21	3.20	$ 0.52
Ningbo	1.10	$ 0.18	3.20	$ 0.52
Shenzheng	1.50	$ 0.24	3.20	$ 0.52
Jinan	1.40	$ 0.23	3.15	$ 0.51
Nanjing	0.72	$ 0.12	3.10	$ 0.51
Huhehaote	0.75	$ 0.12	3.00	$ 0.49
Shanghai	0.88	$ 0.14	2.93	$ 0.48
Dalian	1.80	$ 0.29	2.90	$ 0.47
Taiyuan	1.20	$ 0.20	2.90	$ 0.47
Xian	1.29	$ 0.21	2.90	$ 0.47
Guangzhou	0.70	$ 0.11	2.88	$ 0.47
Chendu	1.05	$ 0.17	2.85	$ 0.46
Xiameng	1.80	$ 0.29	2.80	$ 0.46
Fuzhou	1.00	$ 0.16	2.55	$ 0.42
Changchun	1.85	$ 0.30	2.50	$ 0.41

The second Wave of Water PPPs in China

- The measured introduced after 2002, specially the significant increase in water tariffs, resulted in the second wave of water PPPs in China
- From 2001 to 2012, there were 237 PPP in water and sanitation in China, accounting for 40% of the total number of such projects globally. Compared to projects in the first wave, the Equity Joint Venture (EJV) model, under foreign investors enter partnership with local water companies, has been considered as a favorable option to foreign investors instead of CJV.

Foreign and Domestic Firms Active in China's Water and Sanitation Sector

	Sewage Treatment Capacity (10,000 m3/day)	Water Treatment Capacity (10,000 m3/day)	Total Capacity
Veolia	355.9	981	1,336.90
Beijing Capital	372	435	807
Sino-French	31	468.5	499.5
Shenzhen Water Group	57	373.5	430.5
General	115	302	417
Capital Environmental Protection	330	46	376
Beijing Sound Group	102	59	161
China Water Industry Investment Co	4	146	150
China Gas Hong Kong		135	135
China Water Affairs Group	5	129	134
Tsinghua Dongfang		126	126
Everbright Environment		122	122
Golden State Environment	57.1	58.5	115.6
Z.K.C. Environmental Group		104.5	104.5
Asia Water Technology	57	21	78
Bio Treat Technology		77	77
Beijing Drainage Group	46	30	76
Thunip Holdings	65	5	70
Berlinwasser		63	63
Asia Evnironment	10.5	50	60.5

Institutional Issues Water for PPPs in China

- The absence of credible regulatory mechanisms such as economic regulation and tariff determination will undermine long-term prospects of PPPs in China
- The public hearing, as the primary mechanism for tariff review, has not been effective in filling the gap created by the "policy vacuum" in regulatory oversight.
- There is a strong bias favoring projects involving significant private sector investment, as the performance of key local government officials is often evaluated by their success in attracting such investments.

Lesson 1. Water tariff reform is a necessary condition for the development of sound PPPs in the water and sanitation sector

- One of the main reasons for the private sector’s lukewarm response to the Indian government's plans for developing PPPs in the water and sanitation sector is the low water tariff.
- In China one of the main drivers for the boom in investments in PPPs and improvement in service delivery during the mid-2000s was that many cities significantly increased their water tariffs.
  - Because of this, private sector investments have actually increased, even though guaranteed rates of return are no longer offered to investors.

Average Water Tariff in Major Cities in India, 2007

	Rs/m3	USD/m3
Bangalore	20.6	0.33
Chennai	10.9	0.17
Amritsar	9.3	0.15
Vizag	8.6	0.14
Nagpur	6.6	0.11
Rajkot	5.1	0.08
Chandigarh	5	0.08
Mumbai	4.6	0.07
Jamshedpur	4.5	0.07
Nashik	4.3	0.07
Counbatore	3.7	0.06
Varanasi	3.2	0.05
Indore	2.8	0.04
Vijayawada	2.2	0.04
Surat	1.7	0.03
Jabalpur	1.5	0.02
Ahmedabad	1.4	0.02
Kolkata	1.1	0.02
Bhopal	0.6	0.01
Mathura	0.6	0.01
All India Average	4.9	0.08

Average Water Tariff in Major Cities in China, 2000-2012

	2000		2012	
	RMB/m3	USD/m3	RMB/m3	USD/m3
Tianjin	1.60	$ 0.26	4.90	$ 0.80
Beijing	1.40	$ 0.23	4.00	$ 0.65
Shijiazhuang	1.10	$ 0.18	3.63	$ 0.59
Chongqing	1.02	$ 0.17	3.50	$ 0.57
Kunming	0.85	$ 0.14	3.45	$ 0.56
Haerbing	1.30	$ 0.21	3.20	$ 0.52
Ningbo	1.10	$ 0.18	3.20	$ 0.52
Shenzheng	1.50	$ 0.24	3.20	$ 0.52
Jinan	1.40	$ 0.23	3.15	$ 0.51
Nanjing	0.72	$ 0.12	3.10	$ 0.51
Huhehaote	0.75	$ 0.12	3.00	$ 0.49
Shanghai	0.88	$ 0.14	2.93	$ 0.48
Dalian	1.80	$ 0.29	2.90	$ 0.47
Taiyuan	1.20	$ 0.20	2.90	$ 0.47
Xian	1.29	$ 0.21	2.90	$ 0.47
Guangzhou	0.70	$ 0.11	2.88	$ 0.47
Chendu	1.05	$ 0.17	2.85	$ 0.46
Xiameng	1.80	$ 0.29	2.80	$ 0.46
Fuzhou	1.00	$ 0.16	2.55	$ 0.42
Changchun	1.85	$ 0.30	2.50	$ 0.41

Lesson 2. Strong support and oversight from the national government is essential for the development of PPPs in the water and sanitation sector

- The experience in China shows that strong support and oversight from the central government is essential to smooth operations and lasting success.
- The decision made by the Chinese central government to "rationalize" water tariffs toward cost recovery and efficient water use was a monumental step in fostering an enabling an environment for the effective development of PPPs in the water and sanitation sector.
- *The Chinese government's involvement of the Asian Development Bank to assist in the development of national guidelines for setting water tariffs, through two Technical Assistant programs, was instrumental in policy improvements reaardina water tariff reform in China.*

Lesson 3. Credible regulatory mechanisms must be in place for the sustainability of PPPs in the water and sanitation sector

- A costly mistake in the development of PPPs in the water and sanitation sector in China has been the neglect of unified and rationalized regulatory mechanisms.
- The absence of credible regulatory mechanisms may have detrimental impacts on the sustainability of PPPs in a water and sanitation sector in the long run.
- The lack of regulatory mechanisms has also had negative impacts on progress toward gains in efficiency in water utility operations, as local water companies are thus not contractually pressured to seek improvements in this regard.