Looking for a Generic Model Structure for Resilience Assessment: A Case Study of Water Resilience in the Lisbon Region

Wang Zhao[1], Igor Oliveira[1], and Birgit Kopainsky[2]

1. European Master in System Dynamics, Department of Geography, University of Bergen, Bergen, Norway

2. System Dynamics Group, Department of Geography, University of Bergen, Bergen, Norway

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This paper builds on a consulting project with a Lisbon civil society organization to assess water resilience using system dynamics model, and the authors' subsequent effort to find a generic model structure as a general starting point to conceptualize social-ecological systems for resilience assessment.

The client organization initially aimed to build an assessment tool that uses resilience for risk analysis, that is easy to use by multiple agents, able to continuously inform the region about how close to collapse the society is, and with a special focus on water stress suffered by low income population.

Our consulting engagement therefore comprised mainly two objectives: helping the organization to redefine the boundaries of the project as *the Lisbonian water supply system resilience to changes in precipitation* in order to focus on their most concerned area and developing a model that could assess water resilience from a dynamic perspective. As a theoretical foundation to our consultancy, we adapted the basic components of resilience of social-ecological systems defined in Walker et al. (2004), namely *latitude, resistance, precariousness,* and *panarchy*, in addition to two concepts *adaptability* and *transformability* defined by us as dimensions for assessment. The following system dynamics model was then built from documental analysis using reports and datasets from official and civil sources.

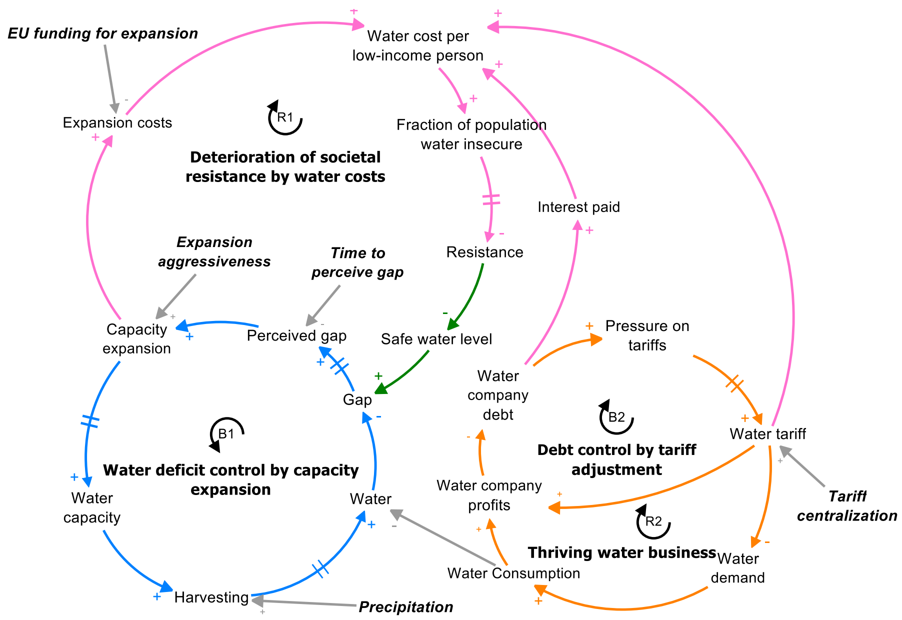


Figure 1. Causal loop diagram including exogenous variables and leverage points. SFD in the supplement.

Throughout the project, excessive time and energy were spent on model conceptualization, due to difficulties in boundary definition in a cross-scale problem. We realized that a better use of generic structures such as canonical situation models (Lane & Smart, 1996) could have helped us perform a more effective intervention. This initiative was enhanced by the long-existing demand to operationalize resilience research (Anderies, Walker and Kinzig, 2006). Moreover, in the field of system dynamics, the current resilience study could also be supplemented with such a generic structure.

We summarized the consulting model as dynamics between *Natural Resources*, *Physical Capital*, and *Policies* (Figure 2), in which the *Natural Resources* and *Physical Capital* fit the concepts *Slow Variable* and *Fast Variable* (Walker el al., 2012). Inspired by the two-stock model used to study the classical Lotka-Volterra behavior (Swart, 1990), we proposed the model in Figure 3 as a generic structure for model-based resilience study. In a word, the model tells that a self-regenerating slow variable suffices the need for a fast variable to develop, and such development influences the slow variable's regeneration.

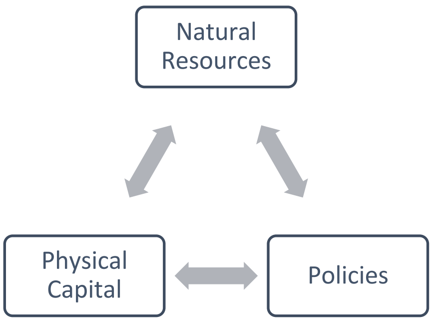


Figure 2. Major aspects to consider when studying the resilience of social-ecological systems

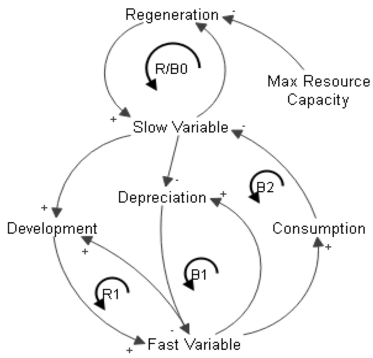
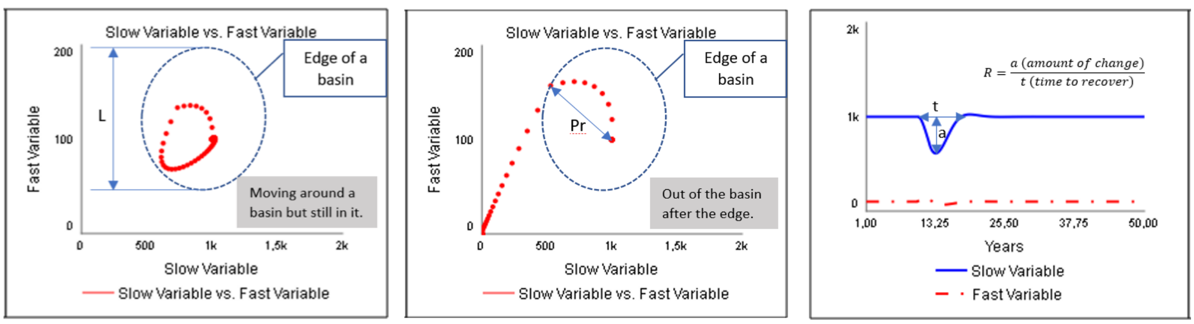


Figure 3. Proposed generic structure in causal loop diagram. See stock-and-flow diagram in full text.

A detailed structural analysis compares the loops in the water resilience model with the loops in the generic structure, concluding that the generic structure could have facilitated our initial conceptualization efforts in the consulting project by providing holistic understanding *a priori*.

Behavioral analysis of the proposed generic structure confirms its ability to both reproduce the behavior of the Lisbon water resilience model and quantitatively illustrate and measure resilience components set forth in Walker et al. (2004), as shown in Figure 4.



a) Latitude b) Precariousness c) Resistance

Figure 4. Resilience components illustrated with behavior of generic structure

We conclude that the use of such structure has a potential to increase system understanding speed and quality. We believe that a social-ecological system could be conceptualized and subsequently assessed by the proposed generic structure, if it fulfills the following 2 assumptions:

1. A slow variable is able to self-regenerate within a certain limit;
2. A fast variable develops to the slow variable's cost.

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