MS-E2177 Seminar on Case Studies in Operations Research 2017

AN APPROACH AND A TOOL FOR WATER RISK ASSESSMENT

Client: Finnish Environment Institute, SYKE

Interim report

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1. Objectives

The overall objective stated in the project plan is the development of an approach and a tool for water-security assessment. This objective has been confirmed.

In the project plan, the overall objective is disaggregated in specific goals. Table 1 reports the overall objective and the specific goals of the project (first column), their current status (second column) and specific comments (third column). As the table shows, all goals have been confirmed and a new one has been added. The new goal is to evaluate the resilience of the context of interest (municipality, region, country, etc.) against water-related risks.

The evaluation of resilience will estimate how laws, policies, institutions and other social factors may amplify or attenuate the impact or likelihood of the risk. This information can be very helpful for the decision maker when trying to mitigate the risk. Nevertheless, the idea of implementing resilience into the tool is relatively recent in the lifetime of the project, hence there are still uncertainties on the time resources available to this new goal. Therefore, the approach is soft, qualitative and an independent part of the tool.

2. Tasks, schedule and resources

Figure 1 shows the updated schedule of the project tasks. The schedule presented in the project plan has been thus far respected (green bars). Instead, the remaining weeks have been reshaped to some extent.

Specifically, there has been a one-week extension (blue bars) to the building of the tool. This extension, considered possible in the project plan already, is motivated by the additional goal of resilience evaluation and by the allocation of more time for refining the tool in terms of result visualization and user experience.

A further extension is that the task of producing a user's guide (which was considered a part of building the tool in the project plan) is here indicated as a stand-alone task, for an improved transparency of the schedule.

The strategy of evenly sharing all tasks among team members has been applied. Small deviations from a perfect sharing division have been that Manu Paloniemi has spent some more time on building the Excel implementation of the tool, while the other team members have spent some more time on building the analytical structure of the tool. Because this strategy has proved successful so far, it will be maintained in the remainder of the project.

Table 1. Overall objective and specific goals of the project: current status and comments.

	Goal	Status	Comments
Overall objective	Develop an approach and a tool for water-security assessment.	Confirmed	The tool is based on a Bayesian network (BN) and Multi-criteria decision analysis (MCDA).
Specific goals	Evaluate and compare impacts and likelihoods of water-related risks, taking into account interactions (causal dependences and synergies) between these risks.	Confirmed	Impacts and likelihoods of risks are evaluated through the analytical structure of the tool, and will be compared through suitable graphs. Causal dependences and synergies are dealt with in the BN and MCDA parts of the tool, respectively.
	Design a tool for use by experts in water security. If data are not available, offer a structure to quickly derive quantitative data from qualitative or semi-quantitative experts' beliefs.	Confirmed	The tool includes elements of MCDA which pertain to the decision maker rather than the experts (value functions, weights). Yet, experts can use the tool by simulating or eliciting the requisite decision maker's preferences.
	Make it possible to assess water security at any spatial and temporal scale.	Confirmed	The spatial scale is inherently determined by the scale to which the risks in the BN and the MCDA hierarchy refer. The temporal scale is determined by the user-defined time horizon of interest.
	Compare the impact on single key dimensions of water security.	Confirmed	As other comparisons performed by the tool, this will be done through suitable graphs.
	Present the results in an illustrative and understandable way.	Confirmed	Graphs will be designed to support the understanding of the numerical results.
	Evaluate the benefits and challenges of the tool, and identify the potential of the tool to be used in the overall water-security assessment of Finland.	Confirmed	Benefits and challenges will be determined by the final balance between usability and complexity of the tool. Consequently, also the potential for large-scale use of the tool will depend on this balance.
	Provide a tool which is easy and quick to use.	Confirmed	The tool will attain a balance between usability and complexity.
	Support the evaluation of resilience against water-related risk.	New	The soft evaluation of resilience based on the concept of social amplification of the risk framework (SARF).

Schedule: Finnish Environment Institute

ACTIVITY	START	DURATION
Initial phase (forming the team, meeting the client, brainstorming)	1	2
Selection of five risks for the analysis	3	3
Conceptual framework of the tool for WS	3	4
Project plan report	5	1
Project plan presentation	6	1
Building the tool for WS	7	10
Interim report and presentation	12	3
Testing the tool for WS	14	3
User's guide	15	2
Evaluation of the benefits and challenges of the approach	16	1
Final report	16	4

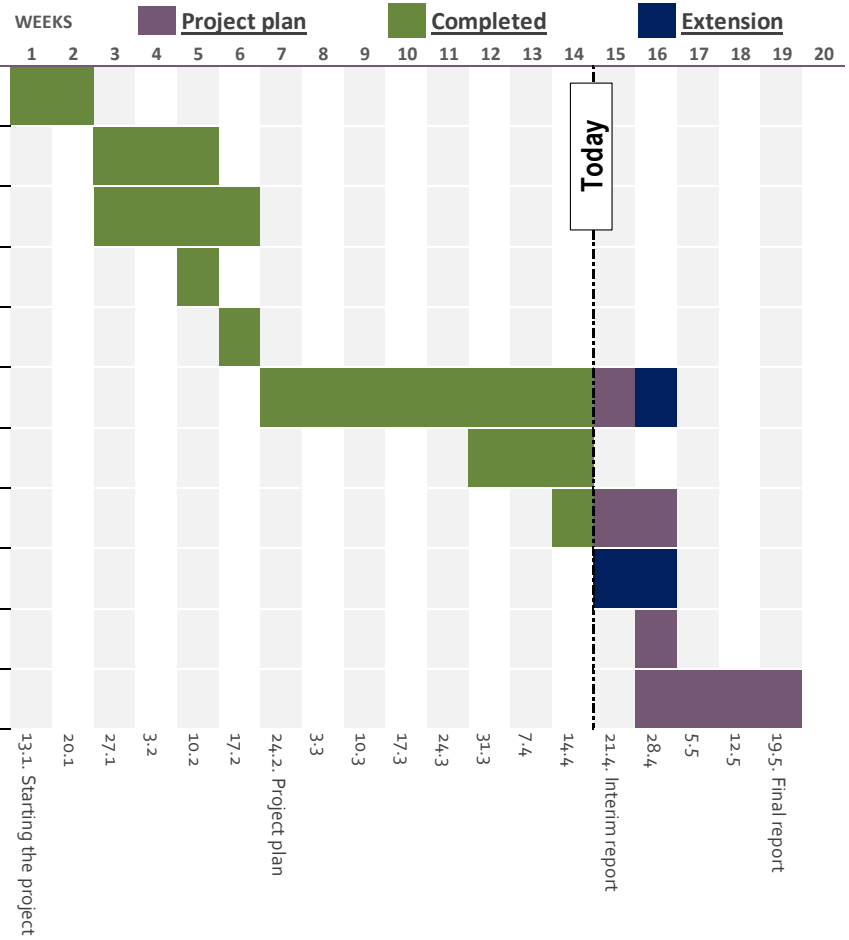

Figure 1. Gantt chart illustrating the updated project schedule. Green and dark blue colors indicate the completed and the extended tasks, respectively.

3. Initial results

The Excel-based tool ultimately provides the user with a Water-security index (WSI). The WSI is a percentage which quantifies water security in the context of interest (municipality, region, country, etc.) under several water-related risks selected by the user.

The various magnitudes of occurrences of the risks define a large amount of risk scenarios, the likelihoods and impacts of which are combined to estimate the WSI. Likelihoods are dealt with in the Bayesian network (BN) of risks. Impacts are dealt with in a Multi-criteria Decision Analysis (MCDA) hierarchy. Both the BN and the MCDA hierarchy require data from the user. If the user possesses real data, he or she shall use them. Otherwise, the tool offers the structure to derive quantitative data from qualitative or semi-quantitative user's beliefs.

A key characteristic of the tool is the treatment of the interactions between the risks. In the BN, interactions are modeled as causal dependences between risk occurrences, while in MCDA hierarchy they are modeled as synergies (or antagonisms) of the impacts.

The MCDA hierarchy has impact at its top, and develops downwards into three layers of decreasing abstraction, namely the key dimensions (KD), the criteria and the indicators. Each scenario impacts on the value of the indicators, whereby such impact is propagated upwards in the MCDA hierarchy by means of (i) impact functions (analogous to value functions in traditional MCDA) at the indicators level and of (ii) weights at the criteria and KDs level. Impact functions and weights should capture the decision maker's preferences.

The tool considers the temporal dimension by requesting from the user the time after which each risk impacts on each indicator, if it occurs. This information serves to disregard impacts realized beyond the time horizon of interest, which is also defined by the user.

The numerical results of the tool are illustrated through suitable graphs. Figure 2 shows impacts and likelihoods of all the scenarios arising from the water-related risks. This cloud of scenarios is converted into the WSI by (i) multiplying likelihood and impact of each scenario, (ii) summing over all the scenarios and (iii) subtracting the obtained number to one. Figure 3 shows the resulting WSI, which is compared for ease of interpretation with the WSI in the selected reference scenario (here, the scenario where no risk occurs). In view of possible risk-management applications, it may be useful to disaggregate the WSI. Figure 4 shows the disaggregation by the three KDs. The disaggregation by risk is made challenging by the synergies. Tentatively, Figure 5 disaggregates the impact on the three KDs by risks, without accounting for the synergies.

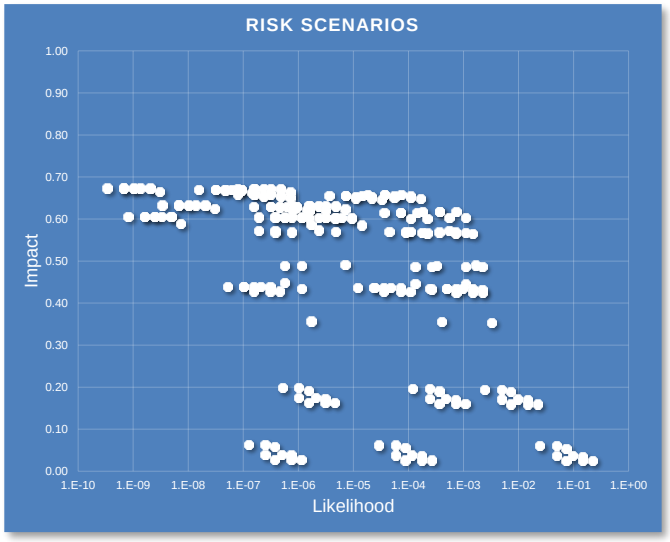

Figure 2. Likelihoods and impacts of all risk scenarios.

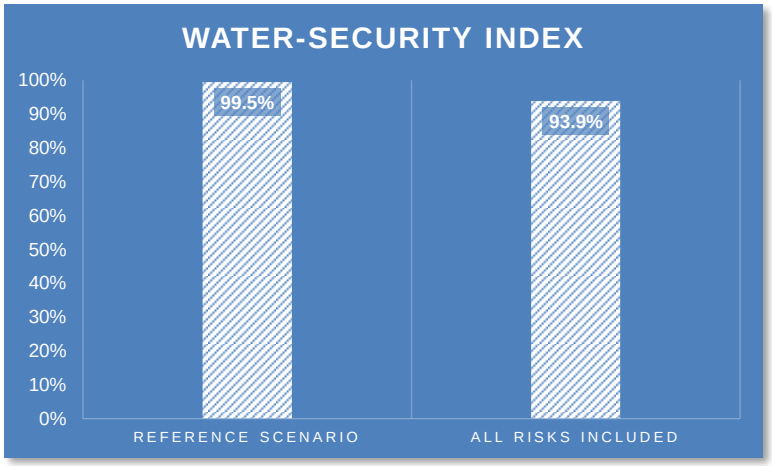

Figure 3. WSI considering all risks under examination (right), compared to the WSI in the reference scenario in which no risk occurs (left).

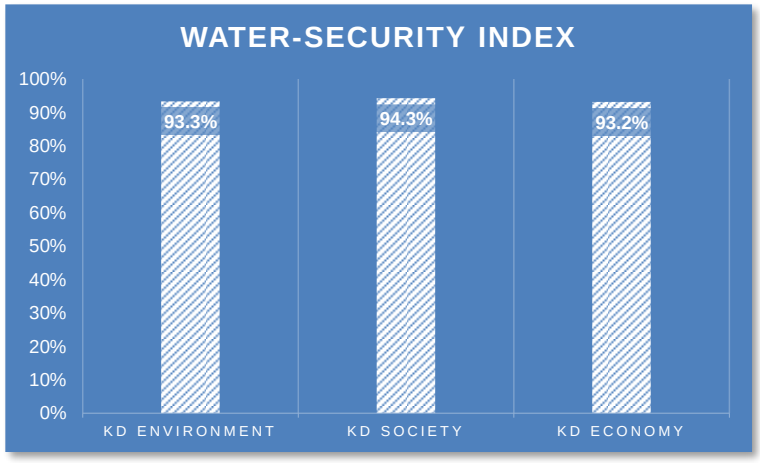

Figure 4. WSI disaggregated by key dimensions.

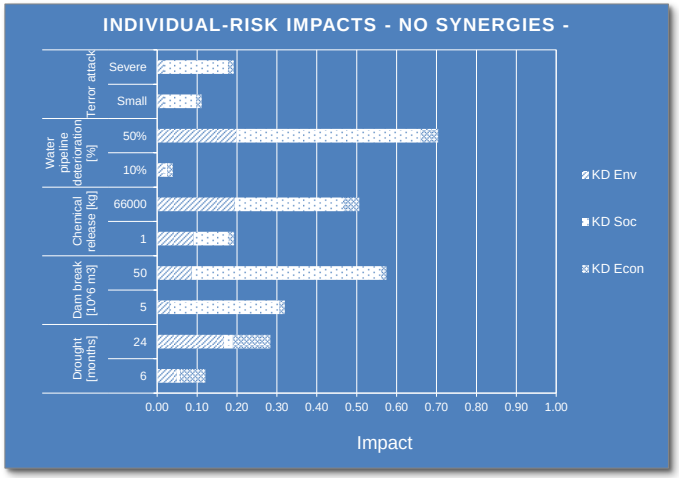

Figure 5. Individual impacts of the risks (synergies not accounted for) divided into the key dimensions of water security.

4. Project risks

In the project plan, several risks that may affect the project were identified, evaluated in terms of likelihood and effects, and addressed through mitigation measures. At the current stage of the project, these risks can be revisited by considering their current status and by updating (if needed) the mitigation measures. The revisited risks are illustrated in Table 2.

Table 2. Current status and mitigation measures of the risks in the project.

Risk	Current status	Mitigation measures
Member absence	Short absences have been easily managed by e-mail communication.	As in project plan
Too large workload	Thus far, the task schedule has been respect in full. The likelihood of delays in finalizing the tool is low.	Delays in refining the tool and in writing the user's guide would affect the usability of the tool, and should hence be avoided. Delays in implementing the evaluation of resilience may be absorbed by re-sizing the scope of this new goal.
Problems with data aquisition	The tool offers the structure to accommodate subjective beliefs, if the expert does not possess the data.	As in project plan
We must make too much simplifying assumptions	The strongest simplifications expected at the time the project plan pertained to providing built-in impact functions and weights in MCDA. Currently, the tool handles impact functions and weights through less strong assumptions than expected.	As in project plan
Model consumes too much experts time	Preliminary checks with the client have not raised excessive concerns about time.	The user's guide can speed up the use of the tool.