MS-E2177 Seminar on Case Studies in Operations Research 2017

AN APPROACH AND A TOOL FOR WATER RISK ASSESSMENT

Client: Finnish Environment Institute, SYKE

Project plan

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1. Background

"*A water-secure world is one where every person has enough safe, affordable, clean water to lead a healthy and productive life and where communities are protected from floods, droughts, and water-borne diseases. Water security (WS) promotes environmental protection and social justice by addressing the conflicts and disputes that arise over shared water resources*" [1].

Key to WS is water management, which is a cross-sectoral activity seeking to ensure secure water for people, food, industry and ecosystems. However, we cannot manage what we cannot measure. By measure, we mean assessing the present state of WS. In keeping with van Beek & Arriens (2014)[1], WS assessment includes (i) identifying the key dimensions of WS (social WS, environmental WS, economic WS etc.), (ii) identifying the risks that threaten the key dimensions (drought, pollution, structural failures etc.), (iii) measuring the impact of the risks on the key dimensions and (iv) comparing the impact against an acceptability target. If the impact is found unacceptable, water-management actions are needed to achieve the target [1].

The choice of water-management actions can be informed by the prioritization of the risks, as recommended by recent theories on the best way to manage national WS [1][2][3]. Nevertheless, many of these theories still remain rather theoretical and lack practical approaches and tools [1][2]. Furthermore, considering the context of Finland, a WS analysis at the national level has never been done.

In order to bridge these gaps, the Strategic Research Council (SRC) at the Academy of Finland has funded the four-years (2016-2019) project "From Failand to Winland" (project website: www.winlandtutkimus.fi). A crucial part of the national WS analysis is a proper WS risk assessment that produces a better way to analyze and manage the water-related risks. Hence, the aim of this seminar project work is to develop an approach and implement a related tool to facilitate the WS assessment process and produce comparable and coherent results of each assessed water risk.

2. Objectives

The overall objective of the project is to develop an approach and a tool for the water security risk assessment. The aim is to evaluate and compare the water related risks in terms of their impacts and likelihood of occurrence. The tool to be developed is designed to be used by the experts, and it could be applied in various levels (e.g. national, regional, municipal). The tool should be able to compare the risks on their total impact on WS, as well as the impact on single key dimensions of the WS. It should present the results in an illustrative and understandable way. Thus, the results of the assessment could be used, when making decisions on WS risk management options. Tool should be tested with five different types of water security related risks, to assure that it works. One objective is also to 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.

The tool will be based on Bayesian belief networks (BN)[4] and Multicriteria decision analysis (MCDA) techniques [5]. The BN approach will be used for the assessment of the likelihood of different risks under different probabilities. MCDA approach will be used in the impact assessment of the risks under consideration. The final tool to be implemented will be a MS Excel based spreadsheet model, built with Visual Basic programming language. The final tool should be easy to use and not time consuming, which requires for special emphasis on the user interface and guidance provided.

3. Tasks

The objectives of the project are pursued through ten specific tasks. The contents of each task and the related responsible persons are briefly illustrated below.

3.1. <u>Initial phase: forming the team – meeting the client – brainstorming (completed)</u>

The project team was formed during the kick-start meeting of the seminar. Later, all team members declared their commitment to the project, and Manu Paloniemi was chosen as the project manager. The meeting with the client was organized approximately one week after the kick-start meeting. The client illustrated the problem statement and indicated the main objectives of the project. In the following week, a brainstorming of initial ideas about the tool was carried out, via both e-mails and meetings. Team members participated to this task evenly.

3.2. *<u>Selection of five risks for the analysis (ongoing)</u>*

Five WS-related risks will be used for testing the tool. The rationale for restricting the number of risks is to focus the team's efforts on the methodological development of the approach, rather than on an extensive collection of literature data. For the selection of the five risks a list of risks identified in a workshop of the Winland project will be used as a starting point.

3.3. <u>Concept model of the tool for WS (ongoing)</u>

The WS-assessment approach is constituted by a Bayesian Network (BN)[4] part and a Multi-criteria Decision Analysis (MCDA)[5] part. In the BN part, different scenarios are formed as risk occurrences with different magnitudes. Causal dependences between the risks are modeled by conditional probabilities. In the MCDA part, the probability and the impact on WS of each scenario are used to assess the overall level of WS. The probability of each scenario is derived by the conditional probabilities of the risks in the BN.

The impact of each scenario is evaluated through a hierarchical structure made of, in decreasing order of abstraction, multiple criteria (i.e. the key dimensions, e.g. urban WS), subcriteria (e.g. access to water supply) and quantitative indicators (e.g. percentage of houses connected to water pipelines). The evaluation also includes (i) synergetic impacts of the risks on specific indicators and (ii) the time horizon of the impact. Thus, probabilities and impacts of the scenarios can be aggregated into a final WS index (in which more is better) and/or used to identify the worst scenarios. As regards WS management, the concept model is still under development. The concept model is being developed during meetings of all team members.

3.4. Project plan report (completed)

The writing of the project plan was shared among all team members.

3.5. Project plan presentation (ongoing)

The presentation of the project plan during the first excursion meeting on February 24, 2017 is being prepared. All team members are preparing the presentation and will talk during it.

3.6. Building the tool for WS (forthcoming)

The building of the tool for WS has three main dimensions. The first dimension is the definition of a formal analytical structure that implements the concept model. This will include, for instance, the way to model synergies between risks (e.g. Cross Impact Analysis[6] and multiplicative coefficients [7]) and the definition of the value functions associated with the indicators in MCDA. The second dimension is the retrieval of the quantitative information for testing the approach: conditional probabilities, the value of the indicators in MCDA in correspondence of the various scenarios, weights of indicators, subcriteria and key dimensions etc. The third dimension concerns the implementation of the approach in a practical tool. The contribution of the team members to the first two dimensions will be rather even. Manu Paloniemi will take the lead in the elaboration of the tool.

3.7. Interim report (forthcoming)

The writing of the interim report will be shared among all team members.

3.8. Testing the tool for WS – sensitivity analysis (forthcoming)

During the final phases of the tool building, basic tests will mainly consist of verifying the consistency of the results with the input (model verification). Successively, testing will address the structure of the approach. Specifically, both the BN and the MCDA part involve strong simplifications for the sake of usability. Sensitivity analysis on the most critical modeling choices will be performed to assess their impact on the final results. The participation of the team members will be determined later on in the project.

3.9. Evaluation of the benefits and challenges of the approach (forthcoming)

The final task in the development of the tool for WS will imply critical reflections on the extent to which the tool meets the project objectives, and on future improvements that can be envisaged. The team members will act in concert in the elaboration of thoughtful reflections.

3.10. Final report (forthcoming)

The writing of the final report will be shared among all team members.

4. Schedule

Our schedule is presented in Figure 1. Our focus is in building the tool and we have reserved most of the time to the process. If we cannot meet the schedule, it is possible to prolong the main phase for a few weeks without critical consequences.

5. Resources

Our team consists of four members: Lauri Ahopelto, Turo Hjerppe, Manu Paloniemi (project manager) and Edoardo Tosoni. The allocation of the resources (working hours) per task and per team member is shown in Figure 2. Supporting resources include the course staff: Professor Ahti Salo and Joonas Lahtinen. Our contact person in Finnish Environment institute (SYKE) is Jyri Mustajoki. He has given us the briefing for the assignment and we will be in contact with him during the process. Also, two members of the group are working at SYKE so we can easily access for example to materials related to the Winland project. Our implementation will be done with Excel. Besides that, we do not have other technical restrictions.

6. Risks

We have identified possible risk affecting the final outcome (Table 1). The risks are evaluated based on the likelihood and impact they might have. In addition, ways to overcome the risks have been proposed. The fact that the risks have been identified already helps the team to proactively avoid them.

Table 1: Possible risks regarding our project.

Risks	Likelihood	Effects	Impact	Mitigation measures
Member absence	Short absence is probable. Complete absence is improbable.	Momentary or permanent increase in the workload of other group members	Low to high	If we manage to keep up with the schedule, small setback will not affect our work
Too large workload	High	All goals set will not be achieved	Moderate	Our project has a very clear target. Thus, we should focus on the main task and then build something extra if we have enough time.
Problems with data aquisition	Very small	We cannot perform the tests for our tool	High	If we cannot acquire expert opinions, we can make educated guesses and see how well the tool works.
We must make too much simplifying assumptions	Moderate	The reliability of the tool suffers	Moderate to high	During the tests, we must keep in mind all the simplifying assumptions we made during the process.
Model consumes too much experts time	Moderate	The tool will not be used.	High	During the tests, we should consider the time the user needs to get the results.

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
Concept model of the tool for WS	3	4
Project plan report	5	1
Project plan presentation	6	1
Building the tool for WS	7	9
Interim report	12	3
Testing the tool for WS (sensitivity anlysis)	14	3
Evaluation of the benefits and challenges of the approach	16	1
Final report	16	4

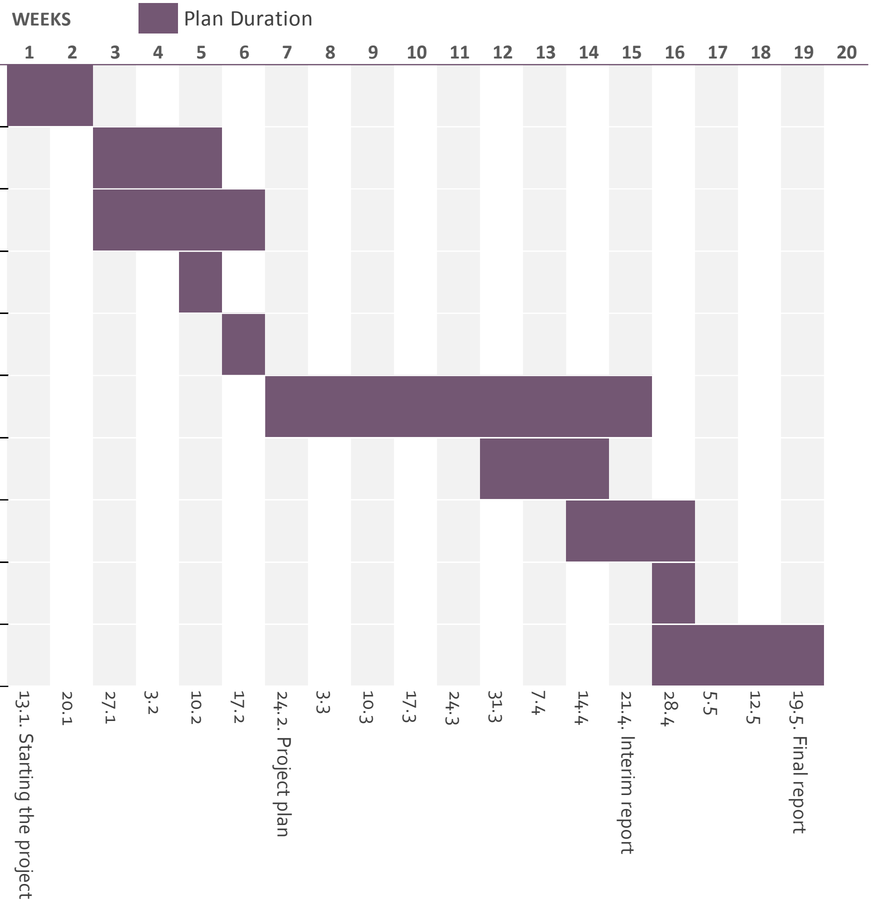

Figure 1: Gantt chart illustrating our project schedule

Allocation of resources - working hours

Task	Edoardo	Lauri	Turo	Manu	Total
Initial phase	10	10	10	15	45
Selection of the risks	15	15	15	15	60
Concept model of the tool	20	20	20	20	80
Project plan and presentation	10	10	10	15	45
Building the tool	35	35	35	45	150
Interim report	5	5	5	15	30
Testing the tool	10	10	10	10	40
Evaluation of the approach	5	5	5	5	20
Final report	15	15	15	30	75
Total	125	125	125	170	545

Figure 2. Allocation of resources (working hours) per task, per team member.

References

1. van Beek E, Arriens WL. Water Security: Putting the Concept into Practice. Global Water Partnership, Stockholm, 2014.
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5. Linkov I, Satterstrom FK, Kiker G, Seager TP, Bridges T. Multicriteria decision analysis: a comprehensive decision approach for management of contaminated sediments. Risk Analysis; 26(1):61-78, 2006.
6. Asan SS, Asan U. Qualitative cross-impact analysis with time consideration. Technological Forecasting & Social Change; 74:627-644, 2007.
7. Lopes YG, de Almeida AT. Assessment of synergies for selecting a project portfolio in the petroleum industry based on a multi-attribute utility function. Journal of Petroleum Science and Engineering; 126:131-140, 2015.