Outlining an ‘Evaluation Continuum’: Structuring Evaluation Methodologies for Infrastructure-Related Decision Making Tools

Alexandr Vasenev(✉), Lorena Montoya, and Dan Ionita

Services, Cybersecurity and Safety Research Group, University of Twente,
7522 NB Enschede, The Netherlands
{a.vasenev,a.l.montoya,d.ionita}@utwente.nl

Abstract. Validation of tools to support decisions on infrastructures evolutions should account for the context of their future use. Thus, the role of evaluation constructs is very important, because it identifies the operational context of a power grid. This paper reviews relevant evaluation methods that focus on partnership, collaborative planning, tool-supported collaborative planning, and individual decisions. We propose a structure called ‘Evaluation Continuum’ that embraces the methods. This paper aims to provide readers with a way to account for constructs relevant for validating tools. The outlined ‘Evaluation continuum’ can be used for planning gaming simulations and stakeholder workshops. It can be also useful for devising questionnaires for such sessions.

Keywords: Evaluation · Validation · Methods · Resilience · Continuum · Infrastructure · Decision making · Collaboration · Smart grid · Management

1 Introduction

With distributed generation changing the power grid, a number of actors, such as transmission and network operators, large consumers, and prosumers, will need to collaboratively manage the grid infrastructure. Specialized software solutions, i.e., tools to assist grid planning and management tasks, should be validated with regards to their purpose: support partnerships, collaborative planning, specific decisions, etc. Validation efforts should therefore account for relevant context factors (i.e., evaluation aspects). Due to the novel nature of this task for the electricity domain, the topic is still under development. Consequently, designing validation sessions can benefit from relevant advances in domains with similar requirements in terms of dependability, and with similar risks, such as the water management domain. Besides facing similar management challenges, water management has been advancing rapidly due to the considerable volume of research on climate change.

This paper first outlines similarities between water- and power-grid management. We then introduce a conceptual framework (the “Evaluation Continuum”) that includes constructs that can be useful to validate tools before putting them to practice. Finally,

E.T. Lau et al. (Eds.): SmartGIFT 2017, LNICST 203, pp. 243–249, 2017.
DOI: 10.1007/978-3-319-61813-5_24

we discuss how this framework can be used for validating tools developed to assist stakeholders to improve the resilience of the power grids.

2 Background

Stakeholder collaboration is vital for improving the resilience of a complex system, such as an urban grid. This was suggested, among others, by the German Federal Office of Civil Protection and Disaster Assistance that analyzed impacts of power outages lasting more than 24 h. The Office stressed the importance of involving infrastructure operators, civil protection authorities and media in disaster response [1]. The US Federal Emergency Management Agency [2] pointed out the need to involve the whole community in enhancing the resilience and security in order to bring stakeholders together, evaluate their needs, get them engaged, and raise awareness.

It is therefore expected that diverse stakeholders should be involved in the modelling and design of critical infrastructure protection [3]. To reach a good understanding of the infrastructure‘s vulnerability, and potential to improve its resilience, these stakeholders need to collaborate. While this situation is novel for the power grid, significant advances have taken place in the water management domain. Similarities between power and water domains, shown next, allows one to consider applying water management approaches to study tools for managing electricity.

2.1 Similarities Between Power- and Water Domains

The energy and water domains share a number of features. It concerns the critical role of the resources, distributed (renewable) generation, storage for peak and off-peak usage, and the increased use of IT (as listed in [4]).

In addition, similarities in management approaches in both domains can be observed. When necessary, important management and process evaluation aspects from the water resource management could be projected to electricity resource management. This is possible because of their similar goals and characteristics. In particular, when a blackout causes energy to become a scarce resource, water management methods can be considered. Specifically, it was suggested [5] that water resource management particularly concerns the following features:

- Water resources are often managed by the Government. Agencies involved in participation programs may therefore be particularly concerned about the cost-effectiveness of tax payers’ resources, and the publics’ perception (e.g., through access and representation);
- Water resource management frequently involves multiple interest groups and sponsoring agencies who may be interested in facilitating dialogues focusing on integrating multiple perspectives;
- Water management decisions might be improved by basing them on the maximum information available. Knowledge inclusion might therefore be considered an important characteristic of a good participation process.

These water management features can be projected to electricity management. They are relevant for planning the grid and managing its behavior during (partial) blackouts. The two latter features highlight the need for knowledge inclusion and involvement of multiple actors. The first one particularly emphasizes the need for fair resource distribution, public perception, and the necessity to consider governmental organizations (e.g., the city planning office in the case of urban grids).

2.2 Resilience Management

From the perspective of resilience, power grid management can also be seen as being similar to water resource management. Specifically, according to [6], resilience management has two aims that apply to both domains: (1) Prevent the system from moving to undesired configurations under stresses; (2) Nurture and preserve the elements that enable the system to renew and reorganize itself following a change.

Clearly, governance of common-pool resources invariably involves trade-offs [7]. These trade-offs exist between different stakeholder goals, between risk aversion and productivity, and between satisfying short- or long-term objectives. In power grid one might account for reaching agreements with prosumers [8]. In water management this could mean balancing salt, water and agricultural productivity [7].

Resilience management should build on a shared understanding of the system, resilience goals, and necessary trade-offs. A considerable amount of systemic feedback, cross-scale dynamic interactions, and institutional learning aspects help structuring this process. Walker et al. [6] propose four generic steps which – although intended for water management – are easily applicable to power grid management:

- Step 1: Description of system (processes, ecosystems, structures, and actors);
- Step 2: Exploring external shocks, plausible policies, and exploring vision;
- Step 3: Resilience analysis of 3–5 scenarios obtained after Step 2. This step can result in a return to either Step 1 or Step 2.
- Step 4: Stakeholder evaluation (processes and products). This step can lead to a return to step 1 or provide outputs to policy and management actions.

In sum, given the similarities between features of grid and water management tasks, one can consider applying evaluation constructs across the domains.

3 Evaluation Continuum

This section outlines an 'evaluation continuum' that sketches high level interrelations between methods used to assess (water) infrastructure planning activities, especially those performed with the help of software tools. We propose to see the activities as part of a larger context, consisting of Technology space (T-space) and Interaction space (I-Space) (Fig. 1).

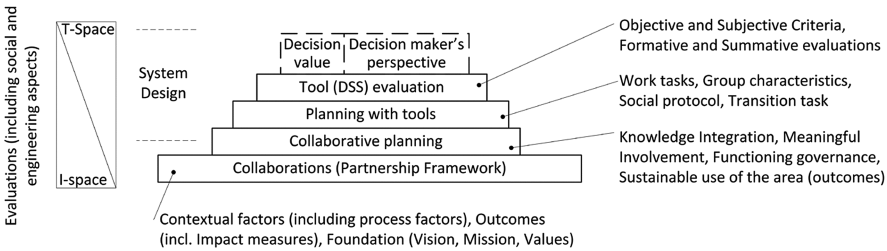

Fig. 1. Evaluation continuum: structuring evaluation constructs

Validation may therefore focus on different aspects relevant to evaluation constructs: collaboration itself, collaborative planning as a process, planning with tools as a part of this process, and tool evaluation. The latter is related to: (1) decision value and (2) perception of decision maker(s). The difference between "tool evaluation" and "planning with tools" concerns the focus of the evaluation activities (see the right part of the Fig. 1 for relevant constructs).

Community collaboration can be evaluated with respect to interactions between participants. This collaboration stays mostly in the interaction domain and is less concerned with specifics of technological solutions. The Partnership Framework developed in Ireland can serve as an example of how one can evaluate this level of interaction [9]. This framework aims at helping individuals and practitioners who are either starting collaboration or need help to strengthen an existing collaboration. The goal of community collaboration is to bring individuals and members of communities, agencies, and organizations together to systematically solve problems that could not be solved by one group alone. Several *Contextual factors* influence and are influenced by the process factors. These factors include connectivity, history of joint work, political climate, policies/laws/regulations, resources, and catalysts. *Process factors* include communication, community development, understanding community, research and evaluation. *The core foundation* is formed by the interrelated Vision, Mission, and Values/Principles. Tools to foster community collaborations in smart grids, similarly to the water domain, might benefit from incorporating views on how actors see the foundation, process, and contextual factors.

A *collaborative planning process* is a process that considers collaborative planning of, e.g., land use and natural areas. Faehnle and Tyrväinen [10] evaluate this process on four dimensions – Knowledge integration, Meaningful involvement, Functioning governance, and Sustainable use of the area (outcomes) – and define several success criteria. These dimensions are important if knowledge from several domains is required, e.g., to identify a suitable location for a large field of solar panels.

Planning with tools concerns evaluation of collaborative systems, when two or more participants attempt to perform a task or solve a problem together using a tool. Compared to the previous framework element, this one concentrates more on how a planning process can be conducted. Systems are evaluated by how well they support various kinds of collaborative work. For this purpose, Cugini et al. [11] describe a 'Collaborative Framework' divided into four levels: requirement, capability, service, and technology. The Technology level is linked to the Service level. The Service level is directed towards the Capability level, which in turn is linked to the Requirement level. The framework can be used in a top-down (requirement level to technology level) or bottom-up fashion. It can be applied, for instance, to study a tool that concerns interactions between grid operators.

Evaluation of *Decision Support Systems (DSS)* – computer-based information systems to support business or organizational decision-making activities – differs from the previous method. Specifically, collaborative planning processes might require using software solutions to model and simulate specific processes and their outcomes. It is not necessary that the tool also promotes collaboration. Therefore, a tool can be evaluated in terms of its ability to support specific decisions. For instance, a tool can concentrate on how incorporating a large water or electricity consumer into the network impacts some system metrics. Three evaluation approaches – a general approach, a three-faceted approach, and a sequential approach – are discussed in [12]. Figure 2 shows the general approach: evaluation criteria influence measurement variables directly and measurement variables relate both to the decision value and to the decision makers' satisfaction. The three-faceted view sees evaluation criteria as a continuum from objective to subjective. Each aspect contains relevant evaluation objects (technical aspects, empirical aspects, and subjective aspects). Objective criteria are related to evaluating technical aspects (e.g., data flow and application control) and empirical aspects (such as cost benefit analysis). Less objective empirical aspects include decision makers' confidence and time taken. Subjective aspects include ease of use, user interface, and understanding.

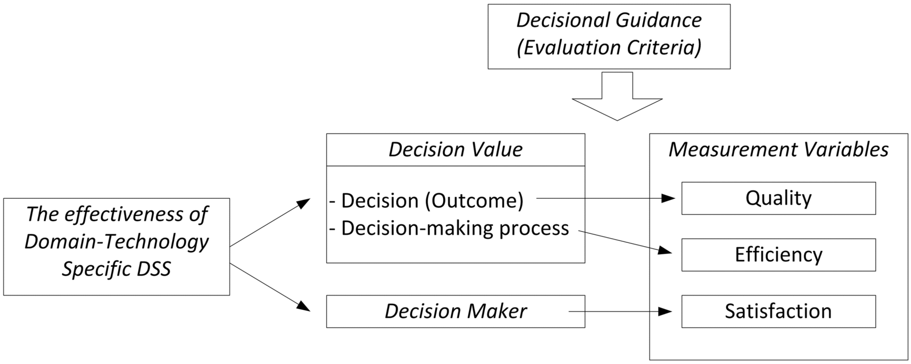

Fig. 2. The general model of DSS evaluation

All the mentioned methods highlight specific features of tools and their use.

4 Discussion on the Utilization of the Evaluation Continuum

The various approaches to evaluation (and their specific constructs) reviewed in the previous section may be useful to design validation efforts, such as stakeholder workshops, focus groups, or serious gaming sessions. In addition, the evaluation frameworks can guide the efforts to devise questions for these sessions. For instance, a workshop organizer could use the outlined Evaluation Continuum to select features and effects of a solution to be investigated. The following process can be envisioned.

First, a construct under study (e.g., resilience) should be defined. For example, one might focus on Engineering resilience, Ecological/ecosystem resilience and social resilience, or Socio-ecological resilience. The resilience plans and strategies can include various activities, such as response-recovery or education-training

Second, constructs (features) relevant to validation efforts need to be specified. For instance, knowledge integration, involvement and other relevant features of the process are to be elaborated. The interfaces between the process and the desired tools should be detailed. Features of the tools might be outlined and metrics assigned to them. Since the evaluation of some features can be complicated, e.g., demand specific domain expertise, indicators and measurement procedures should be specified.

Finally, the organizer might consider system design and systems engineering methods in connection to distinctive characteristics of workshop participants. For instance, less experienced participants of such sessions can provide their view on how a system operates as a whole ('system test' characteristic). More knowledgeable participants could answer questions related to the usability of the solutions. Questions on scalability, specific use cases and limits of applicability can be asked to more experienced practitioners. Specific views on validation constructs are to be collected.

Noteworthy, although similarities between water and grid domains do exist, special features of the grid should be accounted for when devising validation sessions. Electricity is often consumed at the same moment it is produced. Economically viable and efficient storage solutions are not yet in place. Instantly balancing supply and demand is essential. Therefore, decisions on how the grid should operate in normal conditions and under stress should be devised in advance and activated immediately when specific conditions are met. Specifically accounting for these and other features of the grid may result in a variety of framework's instantiations.

In conclusion, the designer of validation efforts (e.g., by means of stakeholder sessions or gaming workshops) could benefit from using the "Evaluation Continuum" constructs. He or she can disambiguate the context and goals of specialized tools, as well as specify measurements to be performed and questions to be asked.

Acknowledgments. This work has been partially supported by the Joint Program Initiative (JPI) Urban Europe via the IRENE project.

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