Designing Sustainable Wastewater Systems: Visual, Interactive Preference Elicitation

Chamberlain, B., Taheri, H., Carenini, G., Poole, D., and Öberg, G.

Introduction

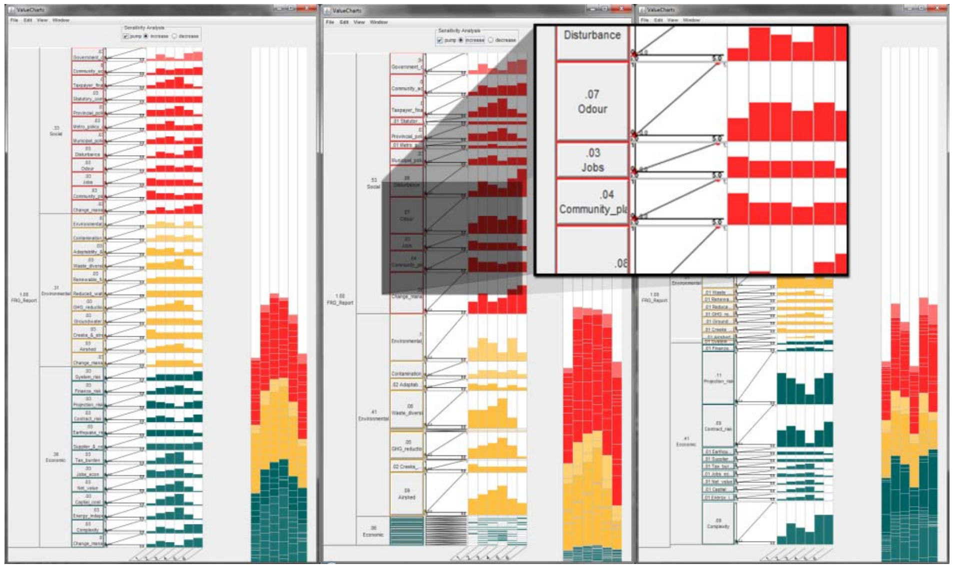
The majority of water and wastewater infrastructures in the industrialized world will require retrofitting and replacement in the near future. Furthermore, there is a growing need for new infrastructure in developing countries. Growing environmental and energy concerns in combination with the challenges involved in securing the quality and quantity of water heighten the urgency of the issue [1-3]. Thus, identifying sustainable solutions requires the simultaneous consideration of economic, ecological and social goals. The challenge is considerable; it is a context-dependent multi-dimensional, multi-objective decision problem in which competing objectives must be identified and trade-offs made [4-7].

Our work aims to create computational tools for wastewater infrastructure design in order to help guide the decision-making process toward more sustainable choices. Thus, we are developing a decision-support system (DSS) to aid decision makers, engineers and related constituents in identifying and selecting alternative wastewater systems which balance environmental, economic and social needs. Our DSS consists of three different modules: 1) constructing a database and ontology about wastewater components, technologies and processes, 2) developing a tool capable of generating possible alternative wastewater treatment systems, and 3) a preference-elicitation method for guiding decision-making and the selection of sustainable alternatives

Our focus here is on the development of Module 3. Unlike traditional static methods for comparing alternatives based on a set of predefined values, we use ValueCharts which provides real-time visual feedback to dynamically changing preferences [8, 9] and has shown to be intuitive and useful for comparing alternatives [10] . ValueCharts has been tested in user studies to comparing alternatives [e.g. 10, 11, 12], and shown to be beneficial for decision-making because it presents an overview of how well an alternative fits the set of user preferences while simultaneously delivering the detailed information for how well an alternative fits a single preference [13, 14]. Our adaptation of ValueCharts is a Multi-Criterion Decision Analysis (MCDA) tool which enables the assessment of various wastewater alternatives through the comparison of a variable number of criteria, their associated groupings and weight functions. The user interacts with ValueCharts by adjusting weights and functions of each criterion to assess the effects of these changing preferences on the evaluation of the alternatives. The tool provides real-time visual feedback enabling the quick comparison of scenarios across each criterion and cumulatively for all criteria. Finally, ValueCharts is based on simple visualization techniques, namely bar charts and staked bar charts; they do not require any sophisticated expertise in information visualization and can be used by a wide range of users.

Methods

To demonstrate the effectiveness of our application, we evaluate it against a recent report completed for the City of North Vancouver, Canada, which compared six wastewater alternatives for the city (Fidelis Resource Group, 2011). As part of the report, the Fidelis Resource Group (FRG) was tasked with estimating the triple bottom-line (TBL) for each alternative, and to make a recommendation as to the most effective option. This was completed by showing the six TBL assessments in a static comparative matrix to visualize the superiority of their final recommendation. We build upon this matrix by applying ValueCharts to the information contained in the matrix. This enables several improvements: 1) real-time interaction with the information contained in the matrix to explore changing preferences, 2) calculating a weighted-sum comparison, and 3) providing a more intuitive visualization that effectively support all the informative comparisons across the different alternatives. The included figure depicts three scenarios showing economic (green), environmental (yellow) and social (red) factors. The figure depicts: the FRG report, in which all three factors are weighted equally (left), a scenario where environmental and social criteria are weighted more heavily (center), and a scenario where specific criteria were selected (right). The outcome of different weight applications are shown by the cumulative bar charts, where each column depicts a different wastewater system.



Conclusion

We have presented a method for comparing various wastewater systems in order to demonstrate how this method can help individuals make more sustainable decisions. This work represents the third module of our DSS. Our next step is to connect Module #2 (the generation of alternatives) directly with this work, so it can aid decision makers in comparing between other alternative wastewater systems in hopes that together they can enable better decision-making. Our adaptation of ValueCharts shows how dynamic preference-elicitation visualization methods enable immediate user feedback, allowing the user to readily explore how differing preference sets and associated weights may effect a final recommendation of a wastewater system. In preliminary discussions with wastewater engineers, they have openly shared how these techniques provide a useful and efficient means to explore different preference models and to perform a sensitivity analysis. This can be useful in the decision-making process for not only making recommendations, but also in eliciting preferences and clarifying which criteria (and their weights) are to be used in making a final decision.

Note: The ValueChart examples herein can be downloaded and explored from: brentchamberlain[dot].org/valuecharts

References

1. O'Riordan, J., et al., *Resources from waste: An integrated approach to managing municipal water and waste systems.* Industrial Biotechnology, 2008. **4**(3): p. 238-245.
2. Chung, G., et al., *A general water supply planning model: Evaluation of decentralized treatment.* Environmental Modelling & Software, 2008. **23**(7): p. 893-905.
3. Muga, H.E. and J.R. Mihelcic, *Sustainability of wastewater treatment technologies.* Journal of Environmental Management, 2008. **88**(3): p. 437-447.
4. Foley, J., et al., *Comprehensive life cycle inventories of alternative wastewater treatment systems.* Water research, 2010. **44**(5): p. 1654-1666.
5. Ching, L., *Eliminating 'Yuck': A Simple Exposition of Media and Social Change in Water Reuse Policies.* Water Resources Development, 2010. **26**(1): p. 111-124.
6. Guest, J.S., et al., *A New Planning and Design Paradigm to Achieve Sustainable Resource Recovery from Wastewater 1.* Environmental Science & Technology, 2009. **43**(16): p. 6126-6130.
7. Balkema, A.J., et al., *Indicators for the sustainability assessment of wastewater treatment systems.* Urban water, 2002. **4**(2): p. 153-161.
8. Carenini, G. and J. Loyd. *ValueCharts: analyzing linear models expressing preferences and evaluations*. 2004. ACM.
9. Bautista, J. and G. Carenini. *An integrated task-based framework for the design and evaluation of visualizations to support preferential choice*. 2006. ACM.
10. Bautista, J. and G. Carenini. *An empirical evaluation of interactive visualizations for preferential choice*. 2008. ACM.
11. Wongsuphasawat, K., et al., *Querying event sequences by exact match or similarity search: Design and empirical evaluation.* Interacting with Computers, 2012. **24**(2): p. 55-68.
12. Pommeranz, A., P. Wiggers, and C. Jonker, *Towards compositional design and evaluation of preference elicitation interfaces.* Human Centered Design, 2011: p. 586-596.
13. Pommeranz, A., et al., *Designing interfaces for explicit preference elicitation: a user-centered investigation of preference representation and elicitation process.* User Modeling and User-Adapted Interaction, 2012: p. 1-41.
14. Pommeranz, A., P. Wiggers, and C. Jonker, *User-centered design of preference elicitation interfaces for decision support*, in *Proceedings of the 6th international conference on HCI in work and learning, life and leisure: workgroup human-computer interaction and usability engineering*2010, Springer-Verlag: Klagenfurt, Austria. p. 14-33.