Activating Values to Enhance e-Participation in Environmental Decision-making

by

Simone Philpot

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Examining Committee Membership

The following served on the Examining Committee for this thesis. The decision of the Examining Committee is by majority vote.

External Examiner	Julia Baird. Assistant Professor. Environmental Sustainability Research Center. Brock University, Ontario, Canada.
Supervisor(s)	Peter A. Johnson. Associate Professor. Geography and Environmental Management. University of Waterloo, Ontario, Canada.
	Keith W. Hipel. University Professor. Systems Design Engineering. University of Waterloo, Ontario, Canada.
Internal Member	Sarah Wolfe Associate Professor School of Environment, Resources, and Sustainability University of Waterloo, Ontario, Canada.
Internal-external Member	Rob de Loë Professor School of Environment, Resources, and Sustainability University of Waterloo, Ontario, Canada.

Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contribution included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contributions

This PhD dissertation is completed using the manuscript option under the guidelines from the joint Waterloo-Laurier Program in Geography. Four manuscripts are presented in Chapters 4, 6, 8, and 10. I am the first author of all of the included papers. These manuscripts are the products of mainly my intellectual efforts including proposing the research questions, designing and implementing the methodology and experiments, analyzing the results and writing all of the reports and resulting manuscripts. During these processes, I discussed the research and writing with my co-authors on a consistent basis, two of whom are my advisors on the research project and one a collaborator. Their roles and contributions are listed in detail along with the plan of submissions. Minor changes in context and formatting have been made to the included manuscripts for the sake of consistency. Any non-trivial changes to published materials are noted in a chapter preceding the manuscript.

The first manuscript is titled "Analysis of a Brownfield Management Conflict in Canada". I wrote this manuscript under supervision of Dr. Peter Johnson and Dr. Keith Hipel. I conducted the design and research needed for this research, and wrote the manuscript. Dr. Hipel and Dr. Johnson reviewed my drafts and consistently offered me suggestions on how to improve my analyses, results interpretation, and the written manuscript. This paper is published in the journal Hydrological Research Letters.

The second manuscript is "Proposal, Design and Evaluation of a Values-centric Decision Support System". I wrote this manuscript supervised by Dr. Peter Johnson and Dr. Keith Hipel. The research design and implementation were conducted by me and I wrote the manuscript. My drafts were consistently reviewed by Dr. Hipel and Dr. Johnson who offered me suggestions on how to improve my analyses, my interpretation of results, and my manuscript. I collaborated on aspects of this paper with Craig Philpot, an application developer who contributed design insights, and developed and wrote the code to operationalize the theories that I develop in this thesis. Craig Philpot contributed important design and implementation ideas as we collaborated extensively on the software platform described in the manuscript for which he is second author, and on the algorithms included as an appendix to this thesis. This paper is currently under review for publication.

The third manuscript is "Analysis of a Below-water Aggregate Mining Case Study in Ontario, Canada using Value-centric Online Citizen Participation". Dr. Peter Johnson and Dr. Keith Hipel supervised me while I wrote this manuscript. I designed and conducted this research, and wrote the manuscript. Dr. Hipel and Dr. Johnson reviewed my drafts and offered me comments on how to improve my analysis, interpretation, and the final written manuscript. This paper in In Press with the Journal of Environmental Planning and Management.

The fourth manuscript is "Identifying Potential Conflict in Land-use Planning using a Values-centered e-Participation Tool: A Canadian Case Study in Aggregate Mining". I wrote this manuscript with supervision by Dr. Peter Johnson and Dr. Keith Hipel. I conducted the design and research, and I wrote the manuscript. Dr. Hipel and Dr. Johnson reviewed my drafts and regularly offered me recommendations on how to improve my analyses, interpretation, and the final written manuscript. This paper has been published in the peer-reviewed Proceedings of the 52nd Hawaii International Conference on System Sciences (HICSS), 2019, held in Maui, Hawaii, USA. The version included in this thesis has been expanded and submitted for review and possible publication in a journal.

Below are the signatures of co-authors indicating that they are in agreement with the evaluation of the roles and contributions for these manuscripts.

First Manuscript: Analysis of a Brownfield Management Conflict in Canada
Co-Authors:

Dr Peter Johnson	
Dr Keith Hipel	

Second Manuscript: Proposal, Design and Evaluation of a Values-centric Decision Support System.
Co-Authors:

Craig Philpot	
Dr Keith Hipel	
Dr Peter Johnson	

Third Manuscript: Analysis of a Below-water Aggregate Mining Case Study in Ontario, Canada using Values-centric Online Citizen Participation.
Co-Authors:

Dr Peter Johnson

Dr Keith Hipel

Fourth Manuscript: Identifying Potential Conflict in Land-use Planning Using a Values-centered e-Participation Tool: A Canadian Case Study in Aggregate Mining.
Co-authors:

Dr Keith Hipel

Dr Peter Johnson

Abstract

A participatory modeling approach is designed to connect citizens and decision-makers during the selection of the most-appropriate alternative solution to an environmental project based on user values systems. First, a novel approach to supporting values-based decision-making is proposed in which *values activation* is prompted using visual feedback and interactive modules in a software program. Next, the design parameters for a prototype software program called P2P-DSS are presented. P2P-DSS is designed in the style of an online survey, with the added capacity to activate values and provide a shared online space connecting individuals with a survey builder. In this thesis, P2P-DSS is proposed, designed, and then applied to a real-world example in environmental project evaluation.

A formal decision-maker with a professional role in the evaluation of an aggregate mining application used P2P-DSS to build a model of the decision from their own perspective. Fifteen volunteers then used P2P-DSS to learn about the issue, provide their individual input in the form of ranked preferences for potential outcomes, and examine the role that values play in their own assessment of the project and the perspective of the model builder. P2P-DSS records every interaction with the software program and participants completed a post-task survey to assess aspects of the system's performance from their perspective. By analyzing both revealed and stated preferences from the formal decision-maker and public participants, the capacity for the P2P-DSS technique to translate some of the known benefits of values-based thinking into a participatory online platform is indicated.

This thesis then addresses the challenge of translating data collected from individuals into collective preference rankings that are useful for decision-makers. With reference to the aggregate mining example, participant input is aggregated using a Modified Borda Count technique. Thus, while values activation is facilitated in this study on an individual basis, the resulting input can be analyzed as group utilities, the possible implications of this information are examined in depth.

Finally, a novel data set emerges from this research with implications for decision-making, communications, and conflict management. That is, a model builder calibrates a model by connecting specific values with option choices. Participants can then register a

‘values protest’ by using interactive software tools in P2P-DSS to challenge the values connections calibrated by the model builder. Values protests have implications for the preferences input by the participant and are stored by P2P-DSS as a data point. Next, analysis is conducted to isolate potential points of conflict based on emergent patterns in those protests. This new dataset reveals aspects of the decision context for which different groups do not have a shared understanding of how their decision-making is driven by their underlying values. Gaining insight into the roots of values-based conflicts can be useful for conflict prediction and management, strategic decision-making, and the fine tuning of communications by stakeholder groups.

This dissertation examines the boundaries and opportunities for values-based participatory modeling. Specifically, through the design and testing of P2P-DSS this work operationalizes the theory of values activation, thereby expanding the reach of values-based decision-making in online settings. Moreover, by testing protocols to aggregate values-based preferences collected at the individual level into group utility rankings, the P2P-DSS approach is prepared to make contributions for group decision-making. Finally, a new type of data, values protests, is generated and discussed, demonstrating how it can be harnessed to understand and contribute to the management of values conflicts in issues of public interest. Finally, while presenting a novel approach to environmental research, this work also demonstrates that some of the perceived limitations of values research, that are discussed in this thesis, deserve reassessment, as the interactive capacity of software programs opens new avenues to expand the reach of values-based decision-making.

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Completing a PhD degree has been incredibly positive and fulfilling experience because of the people who have generously supported me in my work. First and foremost, I wish to thank my incredible co-advisors Dr. Peter Johnson (Associate Professor, Department of Geography and Environmental Management) and Dr. Keith Hipel (University Professor, Department of Systems Design Engineering). While coming from different disciplines, Dr. Hipel and Dr. Johnson have much in common. They are both models for excellence in research, teaching, and supervision. They fostered my curiosity, skills, professional development, and my joy for research. They guided me skillfully while encouraging me to complete a project that reflected my priorities and values. They have been tirelessly generous with their time and expertise, as well as providing personal, intellectual, and financial support throughout my degree. Individually and as a team Dr. Johnson and Dr. Hipel prove that excellence and kindness go hand in hand in academia. Moving forward, I am proud that they will provide the model I will strive to build upon as a researcher and an educator.

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My committee members Dr. Sarah Wolfe (Associate Professor, School of Environment, Resources and Sustainability) and Dr. Rob de Loë (Professor, School of Environment, Resources and Sustainability) have played an important role in improving my work. Our conversations have been lively and thought-provoking, and their comments increased the depth of my work. I am grateful to both Dr. Wolfe and Dr. de Loë for finding the time to improve my thesis, and to provide insightful comments and encouragement along the way. I would also like to thank Dr. Julia Baird (Assistant Professor, Environmental Sustainability Research Centre at Brock University) for her excellent work as my external examiner in carefully assessing my thesis. Her questions and comments contributed to a dynamic and productive discussion at my defence.

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Dedication

Dr. Judith Patterson
(1953-2017)
I would not have started this journey without Dr. Patterson first showing me that there was a place for me in academia, and then encouraging me to take it.

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Chapter 1
Introduction

1.1 Research Motivation and Context

Integrating human dimensions into decision-making models and practice for environmental management is important because resource use is ultimately driven by how people make decisions (Elsawah, Guillaume, Filatova, Rook, & Jakeman, 2015). This thesis focuses on one human dimension that influences decision-making, *values* (Keeney, 1992; Rohan, 2000; Sagiv, Roccas, Cieciuch, & Schwartz, 2017). Everyone has values that impact how they evaluate alternative choices, behaviors, and outcomes (Hitlin & Piliavin, 2004; Sagiv et al., 2017; Schwartz, 2017; Schwartz & Bilsky, 1987). Making those values explicit creates opportunities to better understand decisions made by people and groups, and informs techniques for improving communication and decision-making processes (Elsawah et al., 2015; Keeney, 1992; Pidgeon & Fischhoff, 2011).

This research takes a Decision Sciences approach to studying one way that values-based decision-making can enhance environmental management. The Decision Sciences is characterized by an interdisciplinary approach to addressing problems related to how people make and evaluate decisions (Mengov, 2015). This thesis builds on existing work done by Bessette, Campbell-Arvai, & Arvai, (2016), Brown & Raymond (2014), Gregory, McDaniels, & Fields (2001) and Keeney, (1992), by studying how values can be operationalized to enhance decision-making. This research also expands on work done by Hosack (2007), Hosack & Paradice (2014), Rokeach (1975) and Verplanken & Holland (2002) by focusing on a role for values activation in supporting values-based decision-making. This dissertation makes contributions to environmental management and integrated modeling by expanding the role that values-based decision support systems can have in informing environmental management and decision-making. Section 1.1 presents the research context and motivation driving this thesis, organized by two interrelated themes: (1) Public participation in environmental decision-making and (2) Applications of values research to public participation in environmental decisions.

1.1.1 Public Participation in Environmental Decisions

Participation refers to processes whereby individuals or groups take an active role in the decisions impacting them (Reed, 2008). Public participation is important in environmental management because these management decisions impact the use and conservation of public resources that impact human well-being (McDaniels, Gregory, & Fields, 1999; Priscoli, 2004; UNECE, 1998). Moreover, public participation can have positive learning outcomes for participants (Tippett, Searle, Pahl-Wostl, & Rees, 2005). An informed public can then promote oversight, accountability, and responsibility to formal institutions, and provide important services such as identifying and managing overlooked environmental issues (Savan, Gore, & Morgan, 2004; Savan, Morgan, & Gore, 2003). Public participation may also improve the quality, implementation, and legitimacy of environmental management decisions by informing their development and building community buy-in (Mostert, 2003; Wesselink, Paavola, Fritsch, & Renn, 2011).

Implementing public participation in practice can be challenging. For example, the expertise perceived to be required for evaluating environmental issues can cause individuals to feel ill-equipped to provide input and can be a barrier to trust in public input from the perspective of formal decision-makers (Carr, Blöschl, & Loucks, 2012; Gregory, Fischhoff, & McDaniels, 2005; Nabatchi, 2012; Reed, 2008; Simonovic, 2009). Moreover, participatory processes can be time consuming, may heighten tensions rather than build trust, and can lead to gridlock or disappointment on the part of the public and decision-makers (Compagnon, Chan, & Mert, 2012; Innes & Booher, 2004; Irvin & Stansbury, 2004; Mostert, 2003).

This thesis is not focused on typologies of publics or characteristics of individuals, communities, and stakeholders, however, these concepts are central to any work addressing public participation and some clarification of the language used in this thesis is warranted. Depending on the goals motivating a specific participatory process, ‘public’ can refer to a range of actors, including individuals or communities impacted by a decision, citizens or organizations seeking information, or knowledgeable experts sought out by government officials to aide in decision-making; Accordingly, the concept of public can be thought of in plural form, as ‘publics’, as well as the singular form which is more appropriately used to refer to a specific sub-set of the publics (Schlossberg & Shuford, 2005). For example, Pierce

& Lovrich, (1980) differentiated between the general public, attentive public, and the interested public. Mostert (2003) identifies the public in public participation as non-government actors, including individual citizens, interest groups, and individual companies. Selecting the relevant public for a participatory activity can be based, among other criteria, on pursuing democratic ideals about power distributions (Arnstein, 1969), the vulnerability of individuals or groups to impacts from a decision (Freeman, 1984), their potential to contribute to or obstruct the decision outcome (Mostert, 2003), and the degree of participant interest in and expertise on an issue (Schlossberg & Shuford, 2005).

Throughout this dissertation, the relevant public of interest is individuals who do not have a formalized or professional role in the decision context discussed in the course of this research. This is because one of the goals of this research is to design and test a participatory modeling tool that creates an interactive online space connecting formal decision-makers who have a professional role over a decision with members of the public who lack such a role. Thus, while distinct definitions for the terms, individual, people, citizens, and public may be applied in other contexts, these terms are used interchangeably in this work unless otherwise qualified. This practice is appropriate to this study because of its overall objective of testing a generalized decision support software system for public participation. Flexibility is important in decision support system design, expanding the range of situations to which systems can be applied (Mysiak et al., 2008). Thus, the approach developed and studied in this research is general so that it may be applied in future studies involving different treatments of public participation with differing relevant publics of interest.

This dissertation is focused on one characteristic of environmental management: making decisions with difficult values trade-offs. One obstacle to public participation arises when members of the public are asked to provide input on environmental issues requiring the evaluation of difficult trade-offs, for example, when development and environmental protection goals conflict, or when the benefits of protecting highly valued ecosystems must be compared to the benefits of using desired but destructive ecosystem services. The existing body of research on decision-making shows that people struggle to evaluate these types of trade-offs but that in these cases, structured processes for aiding decision-making can improve the decision-making process from the participant perspective (Cerreta, 2010; Keeney, 1992, 2002). This thesis is particularly focused on existing research recognizing the critical role that values play in decision-making when such trade-offs exist (Dietz, Fitzgerald, & Shwom, 2005; Keeney, 1992, 2006; Roccas & Sagiv, 2017; Schwartz, 2012).

1.1.2 Values in Environmental Decision-making

When people provide their input on environmental issues, they are subject to cognitive and external forces that influence their decision-making (Pidgeon & Fischhoff, 2011). For example, issue framing (Emery, Perks, & Bracken, 2013; Lakoff, 2008, 2010), discounting (Vlek & Keren, 1992), emotions (Slovic, Finucane, Peters, & MacGregor, 2004), personality dimensions (Rustichini, DeYoung, Anderson, & Burks, 2012), unconscious drivers (Wolfe & Brooks, 2017), and diverse heuristic tendencies (Gigerenzer & Gaissmaier, 2011) are just some of the internal factors affecting human decisions. External factors such as economic evaluations, power dynamics, economic and social barriers or advantages, knowledge and uncertainty also impact decision-making (Ariely, 2010; Barnaud, Va Passen, Trebuil, & Promburom, 2006; Cote & Wolfe, 2014; Ostrom, 2000).

While acknowledging the complexity of decision-making, the research presented in this thesis focuses on one factor only, values. Values are chosen for this work because they are implicated in all aspects of decision-making (Brosch & Sander, 2013), being foundational to the preferences and goals that guide decisions (Feather, 1995; Keeney, 1992; Verplanken & Holland, 2002). Although individuals do not always explicitly think about their own values when making everyday decisions, their decision-making can be more purposeful and effective when they do so (Keeney, 1992; Verplanken & Holland, 2002). Moreover, the development of decision models that move beyond assumptions of rational cognition, capturing instead real decision-rules that resonate with users is a best practice in the development and use of decision support systems (Elsawah et al., 2015). Values-based models contribute to this best practice as values have been subject to a wide variety of empirical studies in the fields of decision analysis (Keeney, 1992; Parnell et al., 2013), sociology, and psychology (Grube, Mayton, & Ball-Rokeach, 1994; Hitlin & Piliavin, 2004; Rokeach, 1968; Sagiv, Roccas, Cieciuch, & Schwartz, 2017; Schwartz, 2012), confirming their role in decision-making. Moreover, in addition to describing how people make decisions, values research has been applied prescriptively to improving decision-making

(Arvai, Gregory, & McDaniels, 2001; Cerreta, 2010; Keeney, 1992; Keeney, 1982; Parnell et al., 2013).

Past research indicates that a focus on values has positive impacts on participatory decision-making (Keeney, 1992; Parnell et al., 2013). For example, when using a structured values focused approach, Value-focused Thinking (VFT) (Keeney, 1992), Gregory, Arvai, and McDaniels (2001) found that participants reported learning more about the decision. Gregory, McDaniels, and Fields (2001) noted that VFT participants expressed enthusiasm for the participatory process, and Hostmann, Truffer, Moser, Reichert, and Truffer (2005) found that participants changed their preferences towards consensus decisions during a value-focused intervention. Overall, participants report gaining insights into the preferences of people they disagree with, improving their understanding of their own preferences, and being more satisfied with the process and outcomes of decision-making when systematic examination of their values frames the decision-making process (Gregory, McDaniels, & Fields, 2001; Keeney, 1994; McDaniels, Gregory, & Fields, 1999; Parnell et al., 2013).

Because values are often held sub-consciously, articulating, understanding, and thinking about values to facilitate decision-making is difficult (Keeney, 2006; Roccas, Sagiv, & Navon, 2017). Techniques to implement values-based thinking typically require participants to learn systematic approaches to articulate and organize their own values, rely on the presence of a skilled facilitator, and are limited in the number of participants who can engage in the required activities (Bessette, Campbell-Arvai, & Arvai, 2016; Gregory, 2000b; Keeney, 2004). In an effort to expand the reach of values-based approaches, Bessette, Campbell-Arvai, and Arvai (2016) developed and tested a participatory online program that aides users in making decisions that are consistent with their own objectives and values. Their results were mixed, finding that their experimental software program increased participant understanding of decisions but with a trade-off in increased mental effort and stress (Bessette et al., 2016).

This context highlights a research gap addressed in this thesis about how computer facilitated modeling techniques might expand access to the benefits of values-based decision-making. This dissertation contributes to that research gap by studying how research on personal values can be combined with techniques from participatory modeling to add a layer of decision support when members of the public are asked to provide input on environmental issues requiring the evaluation of difficult trade-offs. Specifically, this thesis presents an exploratory study in operationalizing the theory of *values activation* (Grube et al., 1994; Rokeach, 1968; Rokeach, 1975) to respond to the challenges associated with addressing values-trade-offs in participatory environmental management.

1.2 Research Scope, Questions, and Objectives

This research responds to the concern that environmental management issues are characterized by value trade-offs, and to the empirically supported assertion that focusing on values may lead to better decision-making processes. There exists a gap between the documented benefits of focusing on values during decision-making and the availability of support for engaging in values-based public participation. Two questions raised by this research gap that guide this research are "How can one operationalize values-based decision-making for enhancing environmental management?" and "What are some of the contributions that operationalizing values-based decision support can offer participatory decision-making?". In this work "operationalize" retains a general definition as a process by which a concept is made usable for decision-makers (Potschin, Haines-Young, & Heink, 2014), but this work is specifically concerned with operationalization using a modeling approach. This is because this work aims to contribute to expanding the reach of online values-based decision support. This thesis will address these research questions by developing and testing a participatory values-based decision support system for environmental management. Towards this goal, three interrelated research objectives are pursued and summarized below:

1) Design, develop, and test a software program operationalizing values to facilitate values-based decision-making during the evaluation of decision alternatives.

2) Identify and illustrate techniques and protocols to generate a collective preference ranking from individual preferences rankings collected using the values-based approach.

3) Evaluate the values-based data collected and examine potential contributions of the dataset to understanding the role of values in environmental conflicts.

1.3 Research Contributions

The importance and originality of this study are that it proposes, implements and then tests a new approach to values-based decision support for participatory decision-making. Specifically, the new approach is based on operationalizing the theory of values activation (Grube et al., 1994; Rokeach, 1968; Rokeach, 1975) using interactive and visual cues in a modeling software program. The process of providing ranked preferences using the values activated approach is then tested with reference to a real-world aggregate mining decision. This dissertation makes contributions to several areas of study. First, this project provides an opportunity to advance the understanding of how values activation can be harnessed to aide environmental decision-making; Second the prototype software system developed and tested in this thesis offers a flexible approach to collecting input that may lead to advancements in the integration of values into decision support and online participation in decision-making (*e-participation*). Finally, this research identifies and analyzes a novel dataset generated in the course of this thesis, known as 'protest clusters', which should offer insights for conflict resolution studies. Altogether, this work aims to advance the role that values research can play in decision support for environmental management and decision-making.

1.4 Literature Review: Defining Values

The concept of values is contested across, and within, various disciplines (Dietz et al., 2005; Hitlin & Piliavin, 2004; Rohan, 2000). As such, it is important to first establish the use of the term in this dissertation. To develop a consistent definition of values Schwartz & Bilsky (1987) identified key attributes that emerge from the psychological and social literature on values. This work indicates that values exist as a type of belief that exhibits five defining attributes, these include values are (a) a type of belief (b) about desirable ends states or behaviors (c) that transcend situations (d) guide evaluations and (e) are ranked by importance (Roccas & Sagiv, 2017; Roccas, Sagiv, Oppenheim, Elster, & Gal, 2014; Schwartz & Bilsky, 1987).

That values are a type of belief ranked in terms of hierarchical importance and desirability distinguishes them from other types of beliefs which are rated on scales of legitimacy (Egan, 1986; Mayton, Ball-Rokeach, & Loges, 1994). Fact-based beliefs are held insofar as they reasonably reflect the perceived state of the external world. Beliefs about how the world works, known as worldviews, while more abstract than fact-based beliefs, are also evaluated in terms of legitimacy (Rohan 2000; Egan 1986). These types of beliefs are prone to change in response to evidence to their contrary and to be re-enforced by the perception that they are accurate. Values, on the other hand are more enduring because they are aspirational, deeply connected to a sense of self rather than to an objective experience, and evaluated in terms of importance. Moreover, unlike other types of beliefs and personality traits which can be associated with positive, neutral, or negative affect, values are linked to goals with positive associations (Egan, 1986; Hitlin & Piliavin, 2004).

While worldviews and values are different, they are, of course related, with worldviews being a function of values. Rohan (2000) proposes meaningful connections between values priorities and worldview. For example, Rohan (2000) posits that people who prioritize self-transcendence values as opposed to self-enhancement values may have a focus on social rather than individual outcomes because in their worldview people are inherently good, while the opposite worldview relates to a values framework that prioritizes self-enhancement.

Values are also distinguishable because they are more abstract than attitudes which are used to evaluate objects or specific outcomes (Rokeach 1973; Hitlin and Pilavian 2004; Rohan 2000). This also means that values are more trans-situational, being more stable across instances and time, while attitudes can be more directly implicated in specific behavioral outcomes because they are more responsive to context (Grube et al., 1994; Hitlin & Piliavin, 2004; Schwartz & Bilsky, 1987).

Norms and values both regulate behavior at the individual and group level, however, similar to attitudes, norms are more situationally specific than values (Roccas & Sagiv, 2010). This is in part because norms originate external to the self, as a push towards ideal action based on the expectations of the broader society, while values are central to the individual sense of self (Hitlin and Pavilian 2004). In short, norms can be seen as constraining behavior based on social expectations while values motivate behavior based on individual goals.

The Theory of Universal Values (TUV) (Schwartz & Bilsky, 1990; Schwartz & Bilsky, 1987; Schwartz, 2012), which is consistent with the definition provided above, is the dominant theory of values in psychology (Gouveia, Milfont, & Guerra, 2014b). The TUV posits that there exist ten generalized types of values associated with specific motivations;

these are known as values domains. These values domains are related to one another in consistent ways and serve to organize a finite number of distinct and interrelated specific values (Schwartz & Bilsky, 1987; Schwartz, 2012).

The near-universality of this values structure is supported by cross-cultural empirical studies conducted on every inhabited continent (Sagiv et al., 2017). For example, early work conducted in Israel and Germany involving a total of 786 participants indicated the likely existence of motivational values structured along a continuum defined by compatibility and conflict between values and the goals they support (Schwartz & Bilsky, 1987). Next, surveys in Israel and Germany were replicated and the TUV was refined with studies in Australia, the United States, Hong Kong, Spain, and Finland with a total of 2937 respondents using alternately ranking and rating formats and varying survey tools (Schwartz, 1992). The TUV has since been supported by studies involving over 10,000 participants including specific occupational groups, religious believers, atheists, and representative samples, measured using different survey tools and methodologies (Hosack, 2007; Roccas & Sagiv, 2010; Schwartz & Butenko, 2014; Schwartz, 2012). The organizational structure of the values described by the TUV was also examined revealing that patterns in compatibility and conflict between values types are based on a highly consistent framework organized by degree of perceived importance (Schwartz, 2017; Schwartz, 1992).

Altogether this body of literature strongly indicates that, for a large number of cultures, ten motivational types of values are used by individuals when assessing the importance and desirability of outcomes and behaviors in their lives. Moreover, the organization of values is such that while their content is near-universal, the relative importance of individual values is not. Finally, values that are highly prioritized are so deeply held for an individual that they become a defining feature of their self-identity (Hitlin, 2003). The existence of a universal and finite set of values domains that are differentiated by their organization indicates that conflicts arise between individuals and groups not because the disputants hold altogether different values, but because their decisions or behaviors are informed by differing values frameworks. In other words, conflicts arise not because of different values but when values frameworks clash (Schwartz, 2014).

The universality of values can never be definitively settled due to the impossibility of studying all cultures and the potential for measurement and sampling errors. However, given the diversity of countries studied and confirmation using varied measurement tools, it is likely that values frameworks as described by the TUV are near-universal or universal (Bardi & Schwartz, 2003; Roccas & Sagiv, 2017; Sagiv et al., 2017; Schwartz, 2012). This is further indicated by a limited but growing number of studies identifying distinct neural correlates of values that resonate well with the TUV, captured using functional magnetic resonance imaging (Brosch, Coppin, Scherer, Schwartz, & Sander, 2011; Brosch & Sander, 2013; Moll et al., 2006).

The potential for values conflicts is a key characteristic of the TUV. Gouveia, Milfont, & Guerra (2014a), however, argue that it is not necessary to assume conflict between non-congruent values, and propose the alternative Functional Theory of Human Values (Gouveia et al., 2014b, 2014a). While this perspective warrants consideration, there is a strong body of literature supporting the position that pursuing behaviors that support specific values comes with a discernable cost to pursuing incompatible values, with the understanding that different individuals and groups may experience such trade-offs in different ways (Roccas & Sagiv, 2017; Schwartz & Bilsky, 1990). For example, pursuing behaviors driven by *benevolence,* which describes values related to caring about the well-being of people you know typically comes at a cost to behaviors drive by *achievement* values, which are associated with personal goals, thus they are incongruent values (Schwartz, 2017; Schwartz & Bilsky, 1990; Schwartz & Bilsky, 1987). While acknowledging that the term values can be defined in different ways in the social sciences, and that there exist competing theoretical approaches within psychology, throughout this dissertation the concept of values is defined as described in this literature review, and theories on values that are used in the course of this thesis are consistent and compatible with the TUV.

1.5 Thesis Outline

Chapter 1 introduces the dissertation context, scope, questions, objectives and includes a literature review defining the concept of values, which is central to this thesis. Chapter 2 summarizes the overall thesis methodology. The remainder of the thesis is organized using the manuscript style which consists of a total of eleven chapters, four of which are manuscripts that have been published or are In Press in academic journals as co-authored publications, or are undergoing peer review as part of the publication process. Each of the manuscripts can be considered conceptually to be a whole, while they also stand alone as separate manuscripts each with their own contribution to the field of environmental management and to this dissertation. Each chapter that is comprised of a manuscript is preceded by a small chapter introducing and contextualizing the manuscript, clarifying the manuscript contributions to the thesis objectives, and addressing considerations that arise in interdisciplinary scholarship such as choices in terminology or discipline specific conventions. Each of the chapters is briefly described below:

- Chapter 2 explains the methodology used to achieve the overall goals of this research.
- Chapter 3 is a short chapter introducing selected concepts in Conflict Resolution and clarifying the contributions of the manuscript included as Chapter 4.
- Chapter 4 is an application of multiple participant decision analysis to a complex environmental problem. This chapter introduces concepts from the field of Conflict Resolution that are key to understanding the design choices described in Chapter 6. Chapter 4 is published in the journal Hydrological Research Letters (Philpot, Johnson, & Hipel, 2017).
- Chapter 5 is a short chapter providing context for and highlighting the contributions of the manuscript included as Chapter 6.
- Chapter 6 is a manuscript that is under review for publication as a journal article. This manuscript proposes a theoretical approach to facilitating values-based decision-making in a participatory modeling program, and then demonstrates and tests one way to operationalize the theoretical approach. One outcome of this manuscript is the development of the Public to Public Decision Support System (P2P-DSS) which is used throughout the rest of this research.
- Chapter 7 is a short chapter that identifies and highlights the contributions of the third manuscript included in this thesis. This chapter also clarifies and contextualizes aspects of the third manuscript which is included in this thesis as Chapter 8.

- Chapter 8 is the third manuscript included in this dissertation. This manuscript is published in the Journal of Environmental Planning and Management (Philpot, Johnson, & Hipel, 2019). In this article data collected using P2P-DSS is analyzed and discussed to address the second research objective. A Modified Borda Count (MBC) protocol is used to generate collective preferences rankings from individual preference data. This contribution expands the reach of the P2P-DSS approach by demonstrating how it can be applied to generate collective preferences rankings that are useful for informing group decision-making.
- Chapter 9 is a short chapter that introduces salient ideas about conflict prediction and resolution. This chapter also explains and clarifies the theoretical contributions made by the manuscript included in Chapter 10.
- Chapter 10 is a manuscript that has been published in the peer-reviewed Proceedings of the Hawaii International Conference on Systems Sciences HICSS-52, 2019 (Philpot, Hipel, & Johnson, 2019), and has been submitted for journal publication. This manuscript proposes a novel dataset, known as values-protests. Values protests are identified by aggregating public participant challenges to values-based model assumptions as collected using P2P-DSS. Chapter 10 introduces and analyzes values protests and examines how characterizing the different values assumptions between users may provide important insights to facilitate conflict resolution and mitigation.
- Chapter 11 summarizes the findings from the previous chapters and examines their contributions to the research questions that guided this thesis. A discussion on current limitations and future research is also included.
- This thesis also includes appendices which contain important information not included in the original manuscripts. Appendix (A) presents the unique implementation algorithm used to develop a graphical expression of a users’ values framework. Appendix (B) includes the questions included in a post-task survey used to explore user perspectives. Appendix (C) provides samples of texts and images that were provided to participants using the P2P-DSS interface. Appendix (D) provides information for accessing the software, P2P-DSS, developed in the course of this thesis.

1.6 Summary of Thesis Introduction

Studies across environmental and non-environmental topics have demonstrated that participatory decision-making can lead to greater satisfaction with decision-making processes and outcomes when participants are guided through focusing on their values (Keeney, 1992; Parnell et al., 2013). However, several crucial challenges remain to expanding the reach of values-based participation in environmental management. For example, methods to focus decision-making on values can be burdensome in terms of time commitments, the need for formal facilitators, and the requirement for users to learn unfamiliar problem structuring techniques (Bessette et al., 2016; Groumpos, 2010). This thesis examines the potential to activate values-based decision-making using a participatory modeling software program. Over the course of four manuscripts this thesis demonstrates a process for modeling human preferences using ranking techniques, proposes and evaluates a technique to access the underlying values that inform preferences, and then tests the prototype system by collecting an illustrative set of values-based preferences, developing collective preferences from individual inputs, and generating a new type of data that may be useful in understanding values-based conflicts. Altogether this work makes contributions to environmental management scholarship by developing and evaluating an approach that may expand the role that values research and decision support system techniques play in environmental decision-making.

Chapter 2
Methodology

2.1 Methodology Overview

Chapter 2 presents an overview of the thesis methodology. A graphical summary of the methodology is provided in Figure 2-1. At times, aspects of the methodology are relevant to the specific manuscripts included in this thesis, in order to avoid repetition these methods are described in detail in the manuscripts to which they are relevant.

2.2 Decision Support Systems

Decision Support Systems (DSS) are software tools that support decision-making by organizing information into useful models that guide analysis of specific aspects of a decision. Specifically, DSS operationalize theoretical methods that assist decision-making, making those theoretical methods accessible to a wider range of users and useful for an increased range of applications (Sage, 1991). For example, the Graph Model for Conflict Resolution (GMCR) (Fang, Hipel, & Kilgour, 1993) is a theoretical approach for strategically analyzing real world conflicts by mathematically expressing the variety of ways that people may behave in conflict situations (Xu, Hipel, Kilgour, & Fang, 2018). While the GMCR methodology does not require computerization, by programming it into a DSS GMCR can be more readily and effectively used to understand actual conflicts. For example, users can access the insights available with GMCR without needing to become experts in the underlying methodology because the DSS completes the necessary computations, allowing users to focus on findings and insights (Xu et al., 2018). Moreover, the DSS can readily analyze conflicts with any number of decision-makers or possible outcomes which could otherwise overwhelm a human analyst, thus it can be applied to a greater variety of conflicts when facilitated with computerization (Fang et al., 1993; Xu et al., 2018). As such, several DSS have been developed to operationalize the Graph Model for Conflict Resolution, these include GMCR, GMCR II and GMCR+ (Fang et al., 1993; Fang & Hipel, 2003; Fang, Hipel, Kilgour, & Peng, 2003; Kilgour & Hipel, 2005; Kinsara, Petersons, Hipel, & Kilgour, 2015a).

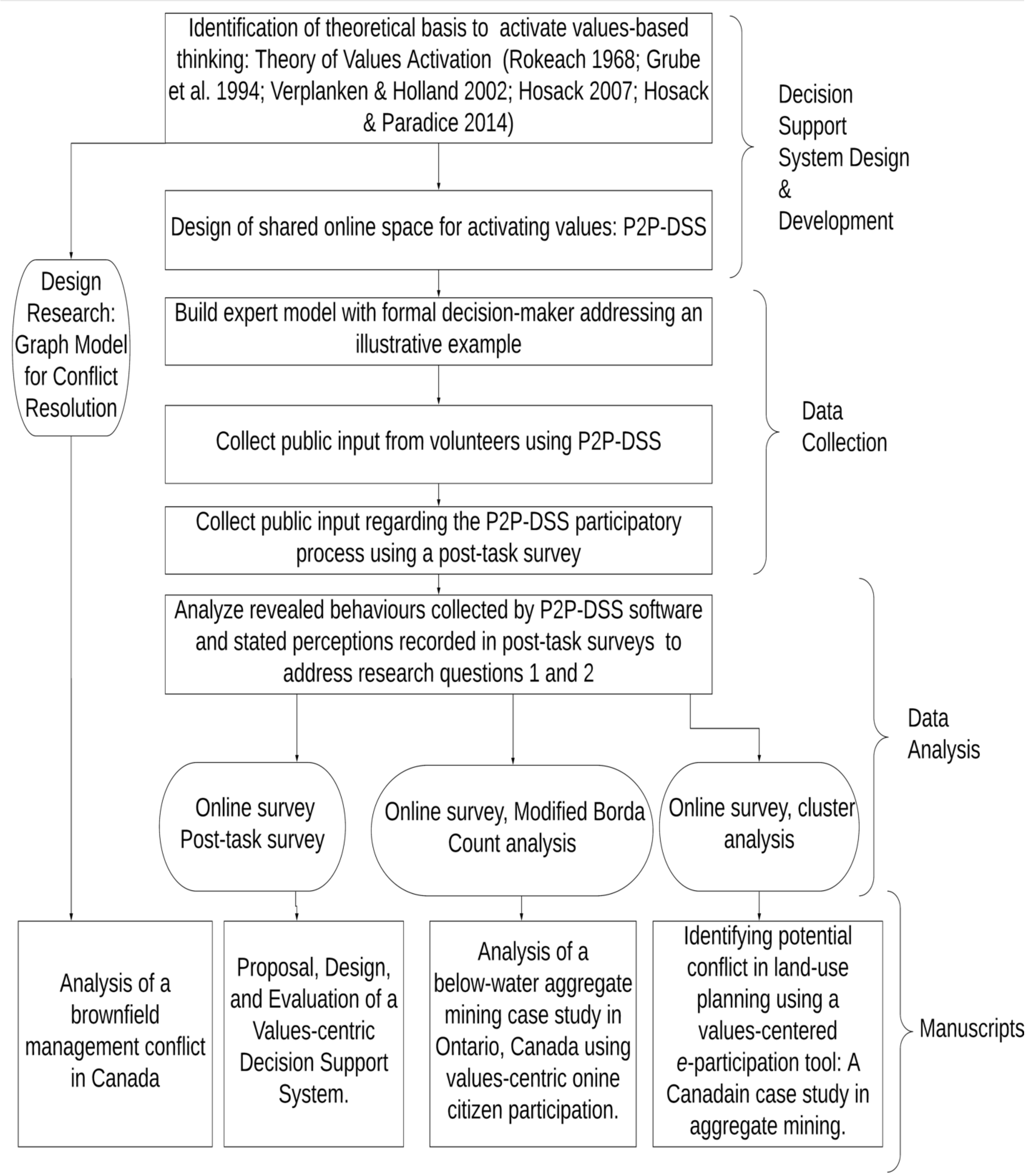

Figure 2-1 Overview of thesis methodology showing primary stages of research including the design and development of P2P-DSS, data collection using P2P-DSS and post-task survey, data analysis, and the resulting four manuscripts included in this thesis.

The manuscript in chapter 6 provides a detailed account of the advancement of DSS technology from a focus on physical systems to social systems, a trend that has informed the methods used in this work. Specifically, as will be discussed in Chapter 6, this thesis argues that a theory from psychology, values activation (Grube et al., 1994; Rokeach, 1968), can be readily operationalized in a DSS, and then proposes, implements and evaluates a prototype values-based DSS known as P2P-DSS.

2.3 Participatory Modeling

Participatory modeling refers to a diverse set of techniques connecting modeling with participation in decision-making (Ginger, 2014; Voinov & Bousquet, 2010). Through design elements that support user involvement in the modeling process, participatory modeling facilitates the integration of the beliefs, values, and assumptions of that user (Haag & Kaupenjohann, 2001). Tools for the analysis and provision of data then facilitate the sharing of perspectives and can contribute to the development of common understandings of the issue or system that is modeled (Basco-carrera, Warren, Beek, & Jonoski, 2017).

2.3.1 Implementing Participatory Modeling in P2P-DSS

Because this research aimed to explore the use of participatory modeling and decision support in expanding the reach of values-based decision-making, the first steps in this research were to identify and operationalize a theoretical approach to activate values-based decision-making that could be integrated into a software program. The theoretical approach and the design parameters used to integrate values into P2P-DSS are described in detail in chapter 6. This research developed and tested P2P-DSS for enhancing deliberation, communication, and data collection related to environmental decision-making.

To apply P2P-DSS to a realistic scenario, a formal decision-maker (F-DM), who is described below, used P2P-DSS to build a model of a decision that fell within their professional domain. Using P2P-DSS, the F-DM made their own assumptions about how values may influence decision-making over the issue explicit within the model.

For example, if an F-DM believes that choosing to accept a petition to extract aggregates below the water table is driven by values that prioritize protecting economic sustainability and development in equal parts, they can calibrate the model to reflect that assumption by selecting the option to accept the petition and then selecting with that option the two value statements related to economic stability and development. They can then set those values statements to have equal weight over the option using a slider feature (Figure 2-2). Whereas if the F-DM believes that the selection is driven largely by a concern for economic stability, with development having a significant but lesser impact and reducing social risk playing a role as well, they may select and weight all three of these values (Figure 2-3). Through this calibration the F-DM models the decision from their own perspective without being asked to apply specific utility values to their judgments.

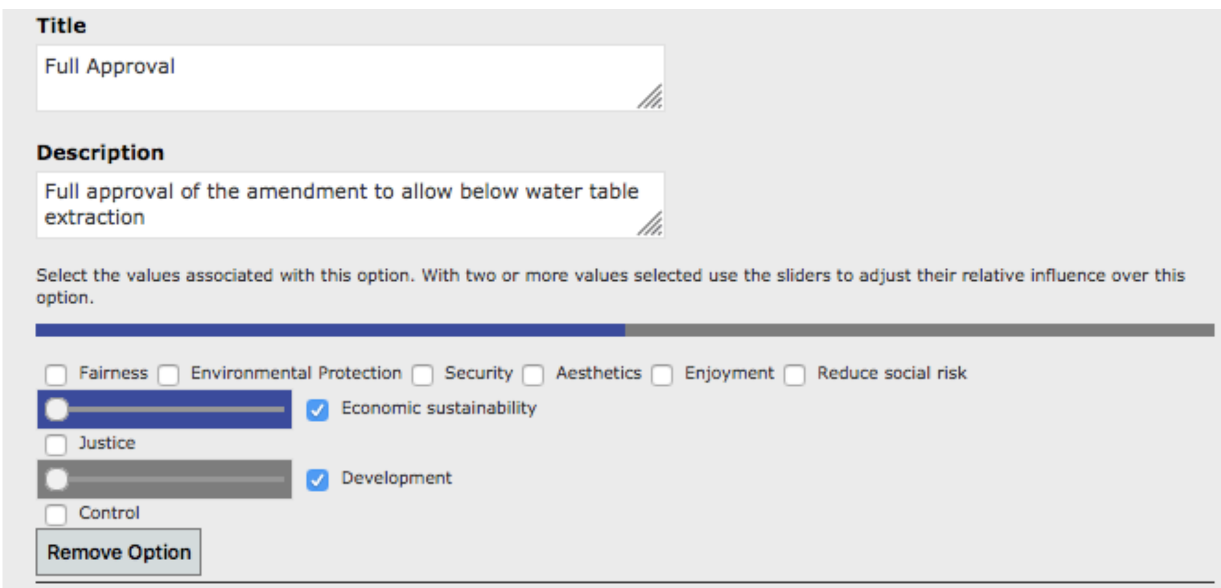

Figure 2-2 Slider feature used to associate options with values in P2P-DSS. Note that in this case the user has associated the option 'Full Approval' with the values: economic sustainability and development with equal weight.

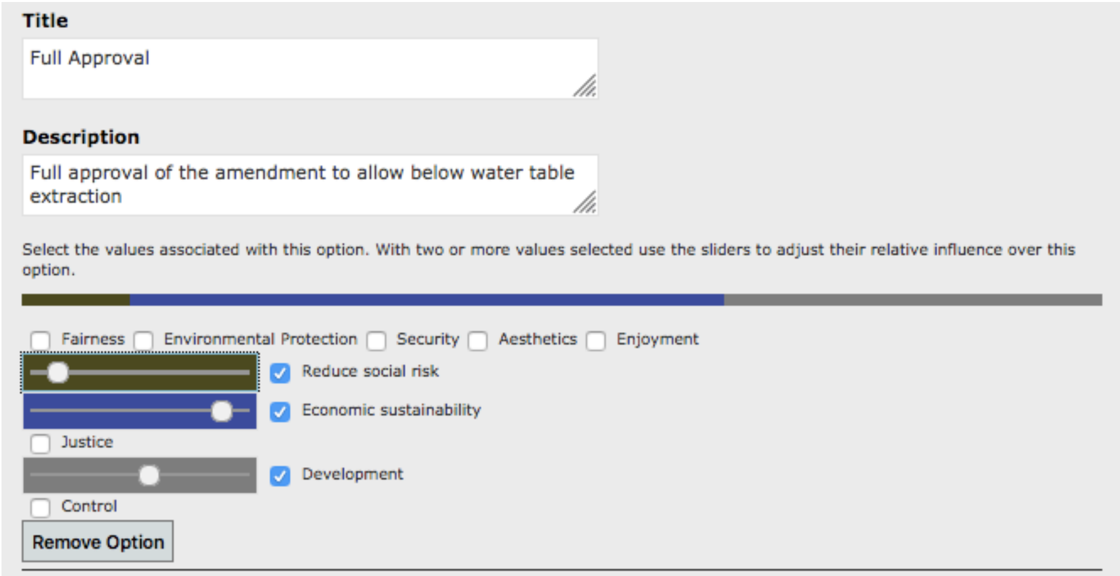

Figure 2-3 Slider features used in P2P-DSS showing an alternative calibration of the Full Approval option. In this case the assumption that choosing this option is driven by values to reduce social risk, economic sustainability, and development are encoded into the model with economic sustainability having the highest weight (most influence).

Survey users then interacted with the model first by reading a short summary of the issue which included links for users who wished to seek more information. Next, users ranked selected proposals from most to least preferred, at this stage they could also create new proposals and add them to that ranking.

Feedback from the software program in the form of a visual representation of the users' values framework as generated by the P2P-DSS algorithms was then used to prompt values-based thinking. A variety of tools then provided ways for users to interact with the model in order to create preferences rankings that were compatible with their own values or to alter the model such that the values-based feedback was considered more accurate. For example, some users changed the proposal rankings, others changed the underlying model parameters previously calibrated by the F-DM, some created new proposals and added them to the rankings, and some users used more than one of these tools in order to create congruence between their preference ranking and their values feedback. Through this process the three outcomes of communication, deliberation, and data collection occurred iteratively.

When using P2P-DSS deliberation occurs when decision-makers or participants (as described below) build a model or use interactive modeling features. These processes, which are described in the following sections, require users to think about how their preferences reflect or do not reflect their personal values and to also consider their values in relation to their preferences. Communication is two-directional. The formal decision-maker communicates their perspective of the decision problem by calibrating model parameters. Public participants communicate their own perspective using interactive modeling elements described below. Data Collection is managed by the P2P-DSS platform which collects and stores a model calibrated by the formal decision-maker and a record of all participant interactions with modeling elements.

It is important to note that participatory processes can be differentiated based on context, specific goals, expectations about the degree of public involvement, and power distribution between formal decision-makers and public participants, differing levels of engagement may be appropriate to specific decision problems (Arnstein, 1969; Collins & Ison, 2009; Reed, 2008). To remain flexible, this approach does not imply any judgment as to how the input from formal decision-makers and participants should be weighted in a final decision judgment.

2.3.2 Implementing Software Feedback to Activate Participant Values

In P2P-DSS, interactive design elements direct users to consider the influence of their own values over their preferences related to a set of pre-defined alternatives. For example, when the F-DM input the option to accept the Jigs Hollow application they were prompted to explicitly identify the values they associated with that choice at that time (Figure 2-2). During this stage of model development, the F-DM was instructed that the model is not intended to be an objective or perfect representation of the decision problem, but an intuitively calibrated representation of their perception at that time. Moreover, they were informed that any participants subsequently using this model would have the opportunity to view and manipulate these calibrations.

For public participants, values were activated first by confronting participants with a visual representation of their values framework as generated by the P2P-DSS algorithms (Appendix A). Interactive elements then provided three ways for users to change the displayed personal values framework until they were satisfied that it was accurate and that their preference rankings expressed their preferences as they intended. All of these elements are described in the manuscript included as Chapter 6. Again, the values feedback is informed in part by the subjective calibrations input by the formal decision-maker. The objective accuracy of the representation of the participants values was not important, instead confronting and thinking about the visual feedback is expected to activate values-based thinking. Prior to using P2P-DSS, participants were informed that the model was built by a formal decision-maker and that by interacting with the model they could explore and change the parameters governing the creation of the values framework. The theoretical foundations for this methodology are presented in Chapter 6 along with a description of the implementation techniques used in P2P-DSS.

2.4 Employing an Illustrative Example: The Jigs Hollow Mining Controversy

A real-world decision about an aggregate mining amendment application at a site known as Jigs Hollow in Woolwich, Ontario, was used to illustrate and test P2P-DSS. The history and context of this application are provided in the manuscripts included in this thesis. By focusing on a real-world problem, a decision-maker with a formal role in the aggregate mining issue was integrated into the research process early in development. Early involvement of users is a component of successful decision support system (DSS) development and deployment (Mysiak, Giupponi, & Rosato, 2005). By grounding the model in a real-world event, the researchers had access to a user who provided important input for creating a realistic context to the decision model and insights into system design in terms of the capacity of P2P-DSS to capture and integrate real-world constraints that are relevant to the decision-maker, user friendliness and intuitiveness of design from the model builder perspective, and usefulness.

Because this thesis aims to explore the contributions and challenges of values-based decision support to participatory decision-making, the characteristics of a decision problem important to this study included (1) the decision is under the purview of one or more professional or formal decision-maker(s), (2) the decision is of interest to or will impact members of the public, and (3) the decision involves value trade-offs. The chosen example is an ongoing application by an aggregate mining company to expand their existing mining permit to allow below water-table extraction in a rural town in Ontario, Canada. Descriptions of the Jigs Hollow example are provided in the manuscripts included as chapters 6,8, and 10.

2.5 Participant Recruitment

2.5.1 Formal Decision-maker Recruitment and Characteristics

In this thesis, 'formal decision-maker' (F-DM) refers to any person or entity who has a formalized role in the decision-making process on an issue. Specifically, an F-DM has a professional interest in a decision and a role that provides influence over the decision outcome. The F-DM who participated in this study requested and was granted strict confidentiality related to their participation. Thus, confidentiality concerns limit discussion about the purview, role, or specific expertise of the F-DM who volunteered for this study including any information that could facilitate their identification either directly or indirectly.

Characteristics of an F-DM who would be recruited for this study include (1) the decision under study falls within their professional domain or scope of expertise, in which expertise is recognized as a highly contextual concept addressing a spectrum of knowledge and skills that can be acquired through study, practice, and experience and evaluated in terms of proficiency within a specified domain (Benner, 1982; Drescher et al., 2013) and (2) the F-DM has sufficient knowledge or expertise on the subject related to their role to populate the model.

For this study an F-DM was purposefully recruited (Neuman, 1997) based on their professional interest in the Jigs Hollow decision and their access to expertise that facilitates the development of a decision model. Upon confirming their willingness to engage in this study, the F-DM attended two meetings with the lead researcher. During these meetings the F-DM developed a model using P2P-DSS. The F-DM was able to ask questions about all aspects of the model building process including the meaning of the values used in the program and to make changes to the values that were integrated in the final model. Moreover, the F-DM provided verbal feedback, which was audio-recorded, about their experience using the interface during this time. These recordings are being used to inform interface improvements to P2P-DSS that will be implemented for future studies. The primary goal of the meetings was to populate a decision model related to the Jigs Hollow mining controversy, this process is explained in greater detail in Chapter 6.

2.5.2 Public Participant Recruitment and Characteristics

The third stage of research tested the system from the perspective of participants interacting with the model. The purpose of this stage was to evaluate the capacity for the P2P-DSS to activate values-based decision-making in users who have no formal role in the decision-making process and to identify impacts of this approach on the process of providing input from the participant perspective.

To collect the perspectives of individuals who may be impacted by the Jigs Hollow mining activities efforts were made to recruit participants from the Township of Woolwich. Outreach to community members was pursued through newspaper advertisements, social media, and recruitment posters at places where people congregate such as libraries, grocery stores, and local cafes. Responses to this recruitment effort were poor. Snowball recruitment (Neuman, 1997) was then employed. A volunteer from Woolwich Township who expressed a long-term interest in the Jigs Hollow mining activities reached out to their personal contacts. Five volunteers living the Woolwich Township subsequently volunteered to participate within the time-frame of this research.

More participants were then recruited using email lists at the University of Waterloo resulting in an additional 10 volunteers including both graduate and undergraduate students. Participants ranged in age between 18-25 and 66-75, with more than half identifying as under 25. Ten of the participants identified as female and five as male. Thus, the participants do not represent a representative sample in terms of distribution or sample size for this study. However, in this exploratory research the group size allowed the researcher to observe user interactions to assess specific aspects of the program and to identify priorities for future development.

2.6 Model Calibration

During an in-person meeting the F-DM and researcher discussed and drafted a written description of the issue. The written description and links to further information were then added to the P2P-DSS model using the editing interface. During a second meeting the F-DM verified the information included in the model and then used interactive editing features to populate the model. The modeling process is described in detail in the manuscript included in chapter 6. Overall the system requires (1) information about the decision (2) specific options under consideration (3) a judgment of what social values drive selection of specific options, and (4) proposals created by combining options. Figure 2-4 illustrates this general procedure.

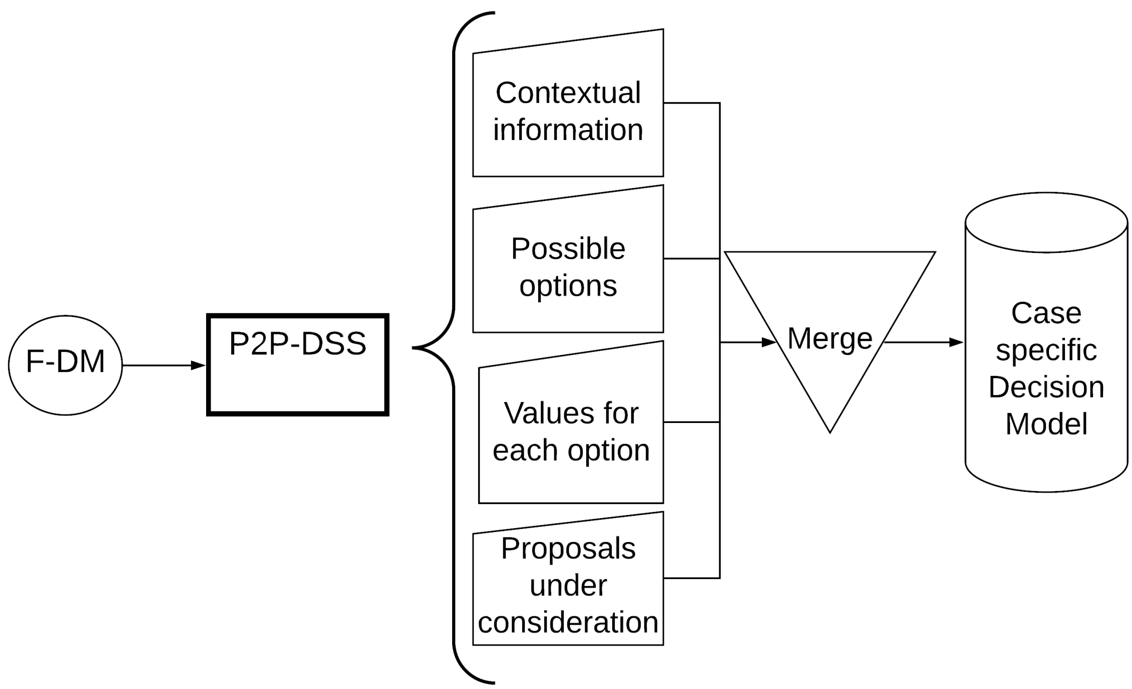

Figure 2-4 Representation of the general procedure for building a decision model using P2P-DSS.

It is important to note that for this study one decision-maker was tasked with building a decision-model, thus the resulting model necessarily represents the perspective of that individual at that time. This subjectivity is not a 'bug' in the system, but rather a design element specifically intended to facilitate the modeling and communication of a perspective to other user groups. The F-DM was instructed that the model did not need to be objective, as survey users would have the opportunity to interact with and adjust the model. By this approach, the formal decision-maker is communicating their own perceptions of the decision context. In future studies it may be possible to build models using groups of F-DMs or to apply tests of model legitimacy, however, this is not necessary for the present study which is focused on evaluation of the approach embedded in P2P-DSS rather than the content of the model.

The F-DM populated model serves as a basis for the next phase of the study in which participants use P2P-DSS to provide their preferences over the possible decision outcomes.

Images of the page of the interface that provides information about the example used in this study are shown in Figure 2-5 and 2-6, and Appendix C includes samples of the text and links that are provided in the Jigs Hollow P2P-DSS model.

2.7 Data Collection

Participants were invited to use and evaluate P2P-DSS at a computer laboratory at the University of Waterloo. Although P2P-DSS can be made available online, this approach allowed the researcher to observe and facilitate aspects of user interactions with the software. Due to novel aspects of the program, this opportunity is important for understanding participant behaviors and responses while using the system, and to retain participants who may request operational support to complete the program tasks. P2P-DSS records all user interactions with time-stamped records of all key strokes including use of all interactive elements and submission of preferences rankings. A survey delivered immediately following completion of the P2P-DSS task was used to evaluate aspects of the program and to complement data generated through analysis of revealed behavior as recorded by P2P-DSS.

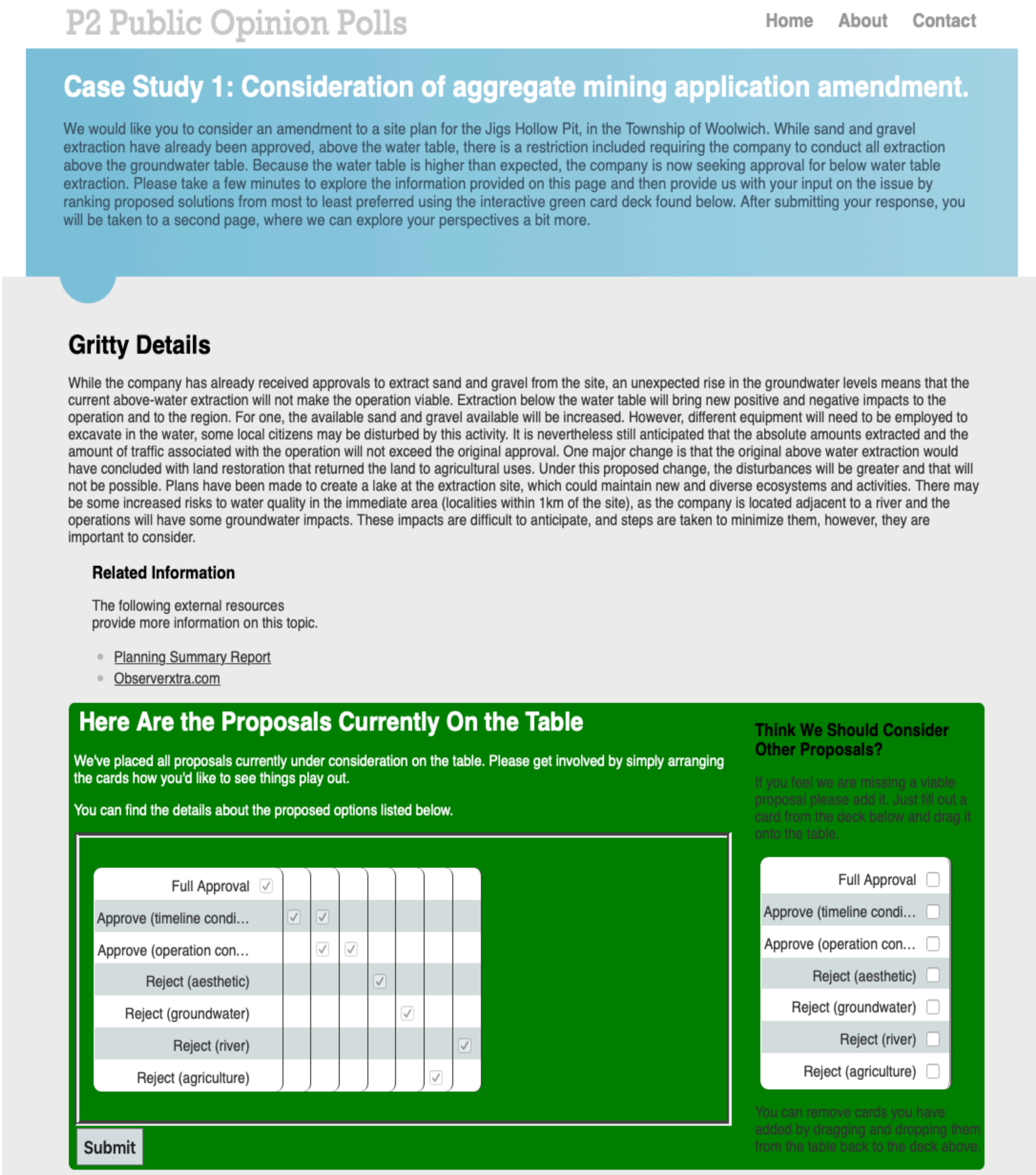

Figure 2-5 The top of the first page of the Jigs Hollow model as seen by participants in this study. A typed version of the text shown here can be found is Appendix C.

Options:

Full Approval

Full approval of the amendment to allow below water table extraction

Approve (timeline conditions)

Conditional Approval. Approve of the amendments only if the approval includes a strict expiry date to control the duration of time for which extraction can continue. After this date, a new approval will be required.

Approve (operation conditions)

Conditional approval that includes restrictions on daily hours of operations. This would limit the noise impact to local residents, but may extend how long the project needs to continue.

Reject (aesthetic)

Reject the amendment application based aesthetic concerns. For example, natural beauty and aesthetic landscape changes will be too great to justify the permit amendment.

Reject (groundwater)

Reject the amendment request based on concerns regarding the potential impacts to local groundwater regime, quality and quantity.

Reject (river)

Reject the amendment based on concerns that below water extraction could impact the flow, quality, and/or quantity of surface water, particularly the nearby river impacts.

Reject (agriculture)

Reject the amendment because below water extraction would permanently change prime agricultural land such that it is no longer fit for agricultural purposes.

Figure 2-6 Content from the first page of the Jigs Hollow model in P2P-DSS. This section, which explains the options included in the model, is accessed by scrolling down along the page. A typed version of this content is included in Chapter 6.

2.7.1 Data Collection Using P2P-DSS

As the P2P-DSS approach is directed at collecting input from non-expert members of the public, the background knowledge of each participant in relation to the topical issue was not assumed. Prior to providing their preference ranking all users could read information about the decision and follow links to learn more about the issue. This information was calibrated as part of the modeling process as described in Section 2.6 and is shown in Figures 2-5 and 2-6.

Participants were then directed to use interactive software elements to rank alternative proposals, which are shown in Figure 2-5, and submit the ranking. Following this submission, participants were taken to the second page of P2P-DSS (Figure 2-7; Figure 2-8) in which they were confronted with a chart that displayed their own personal values framework as estimated by the P2P-DSS algorithms. These algorithms are included in this thesis as Appendix A. Upon consideration of the values framework, participants were invited to resolve any incongruence between their self-perceived values and those reflected in the chart by using the interactive software elements described in the thesis manuscripts.

When a participant is satisfied with both their preference ranking and visualized values framework their input is considered to be preferences-values congruent. Data regarding user interactions was collected by P2P-DSS including all time stamped key strokes, all generated proposals, and changes to model parameters. Participants then completed a post-task questionnaire. Results of data analysis are included in the thesis manuscripts included in Chapters 6, 8, and 10.

2.7.2 Data Collection Using a Post-task Questionnaire

A questionnaire (Appendix B) was used to gain insights into the experience of participants as they used P2P-DSS to provide input on an aggregate mining application decision. The questionnaire consisted of 16 questions, including Likert queries, demographic inputs, and open-ended text responses. Questions were posed to explore how the participant perceived the P2P-DSS approach to impact aspects of their experience providing input on an environmental issue.

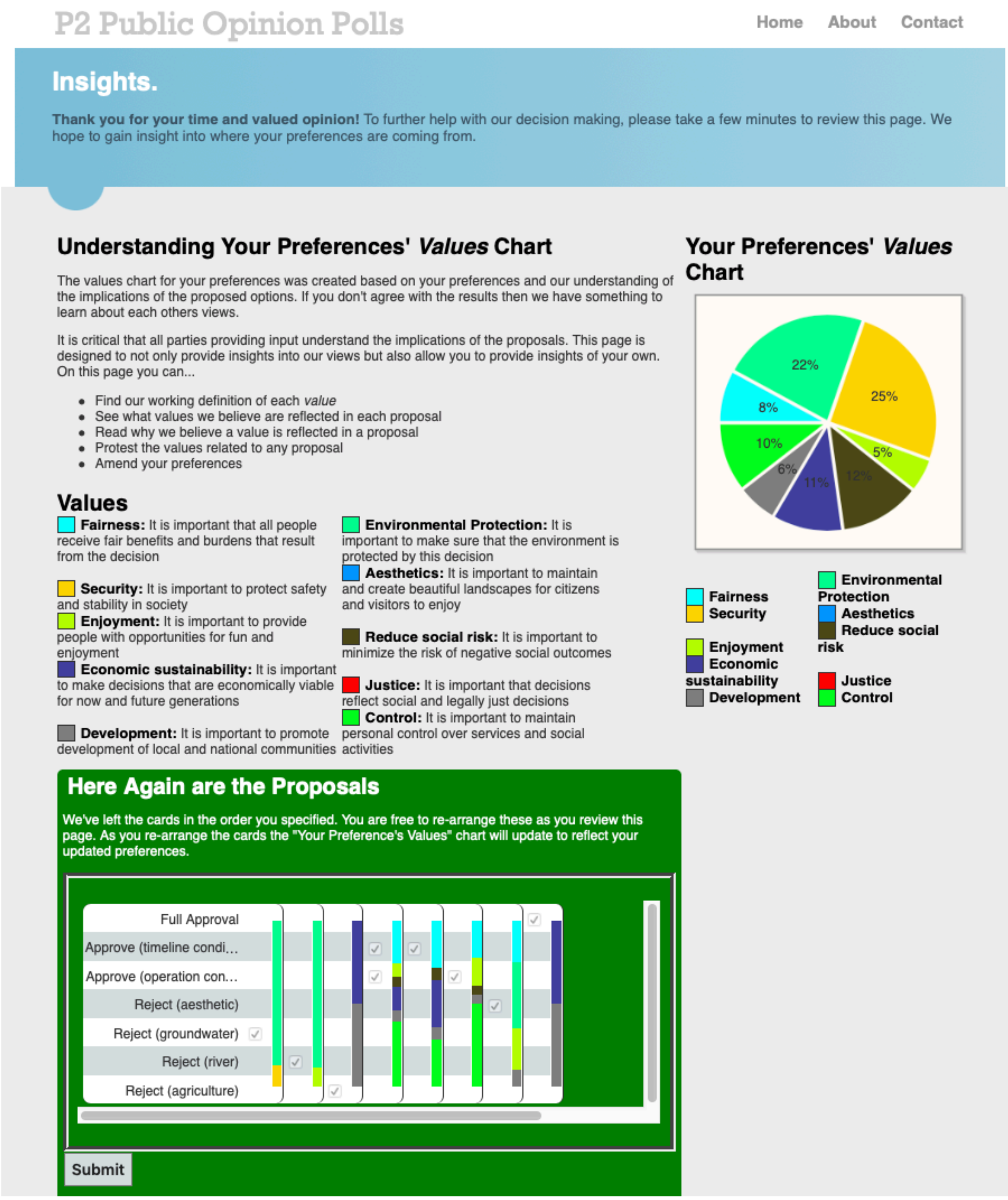

Figure 2-7 Page 2 of the P2P-DSS interface. The visual representation of user values framework, known as the mirror, is shown in the upper right. Note that all elements of this page are designed to focus user attention on values, this includes color coding of all interactive elements and the ever-present mirror which stays in view even when users scroll through the page.

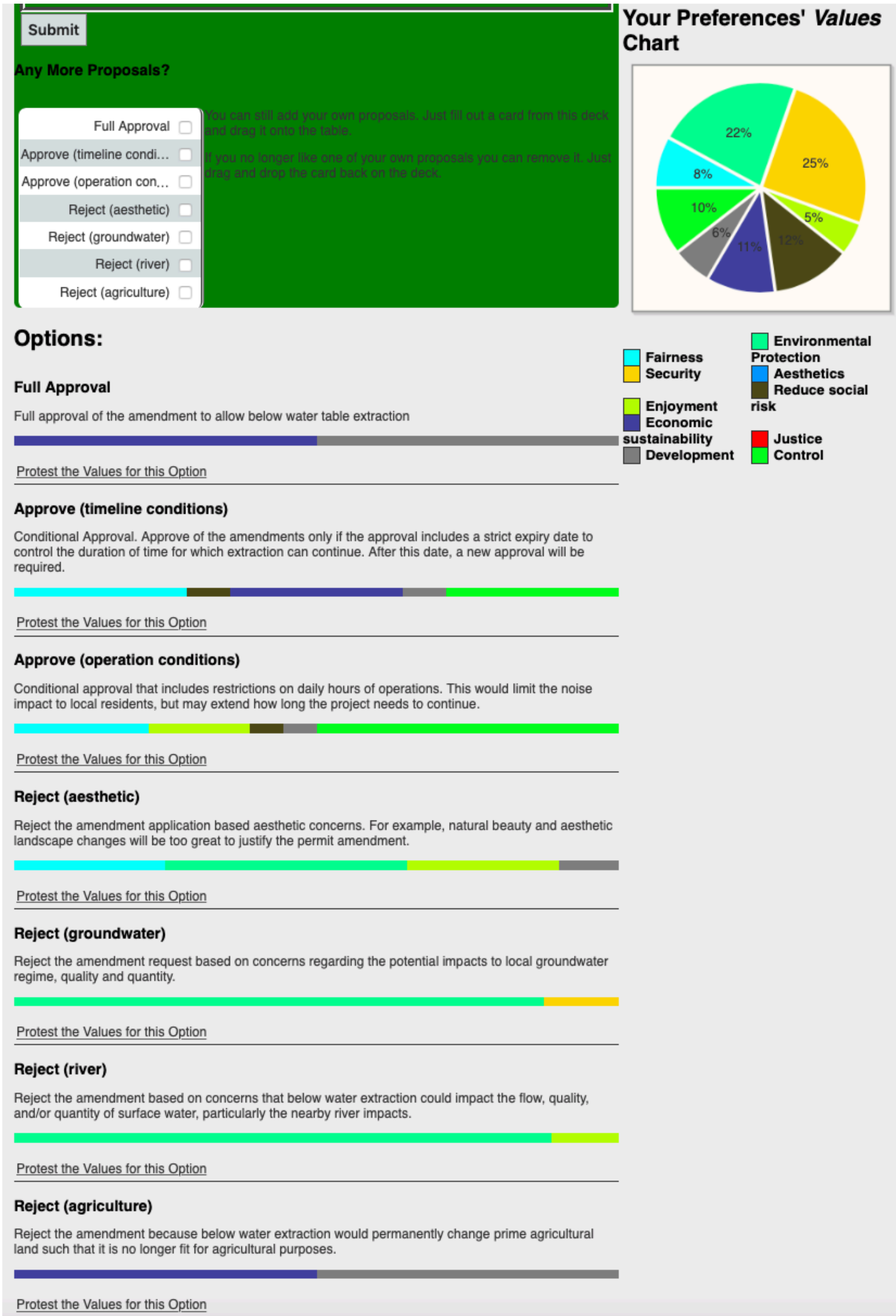

Figure 2-8 Content from page 2 of P2P-DSS that is accessed by scrolling down the page. Note that the color coding continues throughout all elements and the mirror remains in view on the page.

2.8 Analysis

2.8.1 Generating Collective Preferences for Decision Support

P2P-DSS collects individual preference rankings and values-based inputs. Creating a collective preference ranking that may be useful in real-world decision-making addresses the second research objective. A Modified Borda Count (MBC) (Emerson, 2013) was used to generate a collective values-based preference ranking.

A Borda Count takes into account voter preference over the full set of alternatives by distributing individual points to alternatives based on their relative position on each individual ranking and then summing the points applied to each alternative to generate a group preference (de Borda, 1781). In a situation with n alternatives, the most preferred alternative receives n points, the second most preferred receives n-1, and so on until the least preferred option receives 1 point. One disadvantage of this approach, however, is that it cannot fairly handle incomplete responses. For instance, if a participant chooses to only submit his or her favorite proposal, it will receive a much greater advantage over the other options than if a complete set is ranked and submitted (de Borda, 1781; Emerson, 2013). A Modified Borda Count (MBC) is more resilient to such inconsistencies having been developed to address this drawback. The MBC method, which is described in greater detail in Chapter 8 can handle incomplete submissions and incentivizes full participation making it a robust methodology for participatory surveys (Emerson, 2013).

In Chapter 8 an MBC is applied to the ranked input collected with P2P-DSS at three scales including the full participant group, a subset of participants who live closest to the event, a subset of participants living between 10km and 20km of Jigs Hollow and a subset of participants living greater than 20km from the Jigs Hollow site. While the number of participants contributing to this illustrative study limits the insights that can be drawn from the input collected, this research tests the use of the MBC to aggregate data collected using P2P-DSS and proposes its inclusion in protocols for future research with larger study groups.

2.8.2 Analysis of 'Protest Clusters' Generated Using P2P-DSS

Emerging from this work, the manuscript included as Chapter 10 presents a novel dataset that may support conflict management and resolution in environmental management and planning. P2P-DSS provides an option for participants to 'protest' the assumptions of the model developer by altering specific model parameters (Figure 2-9), namely, the stated influence of specific values over options as input by the F-DM. By clustering protests into types, based on the value protested and its combined option, potential conflict hotspots are identified. Then, comparing the protest clusters with the modeling parameters input by the F-DM, aspects of the issue for which different groups do not share a common perspective are identified. This represents a new way to predict and study conflict using participatory modeling that expands on previous work by making values the focus of modeling rather than preferences (Fang et al., 1993) or participatory mapping (Brown & Raymond, 2014; Brown, 2006). Clustered values protests are proposed and examined in detail in the manuscript included as Chapter 10 of this dissertation.

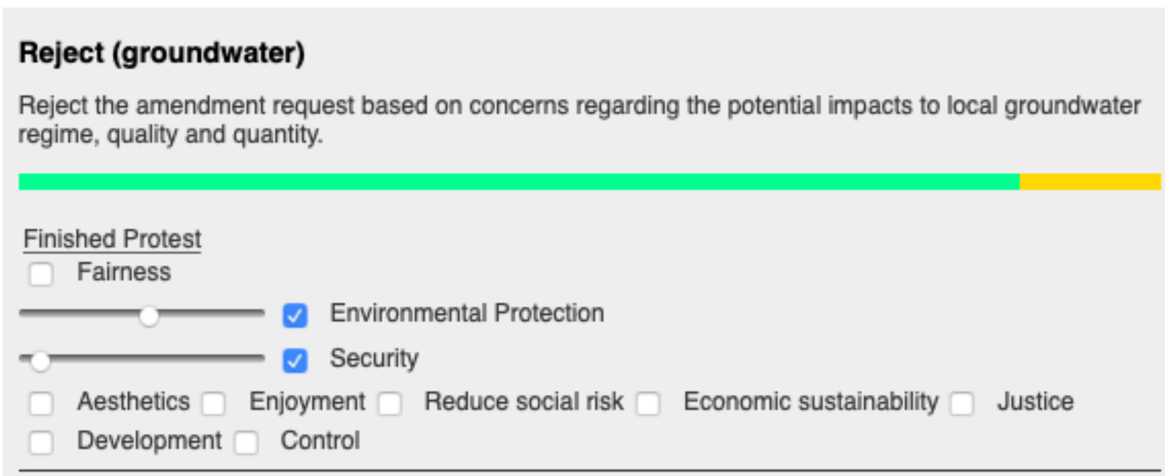

Figure 2-9 Example of the interactive element facilitating 'values protests'. This element provides participants with a way to view and interact with key assumptions embedded in the model. By altering the model parameters, the participant also provides feedback about the decision model.

2.8.3 Post-task Questionnaire

Responses to the post-task questionnaire were used to gain insights into the user experience as participants provided input using P2P-DSS. This was important because the novel interactive aspects of P2P-DSS made interpretation of online interactions difficult. For example, user choice to move an alternative proposal to several different spots on the most to least preferred ranking multiple times could indicate that the user was exploring how their preferences interacted with their values. However, it is also possible that multiple movements reflected difficulty moving the cards using the software interface. Thus, posing questions to directly ask users about their experience was a useful technique to add clarity to the data collected using P2P-DSS. A sample of the post-task questionnaire is provided in Appendix B and participant responses are addressed in the manuscript included as Chapter 6 in this thesis.

2.9 Summary of Thesis Methodology

The methodology supporting this thesis includes decision support system design, participatory modeling, values activation, aggregation by Modified Borda Count, Cluster Analysis, and a post-task questionnaire. The modeling process, methods used to prompt values-based thinking, and post-task questionnaire are described in detail in Chapter 6 and Appendices A and B. Implementation of an MBC is detailed in Chapter 8, and Cluster Analysis is explained in Chapter 10.

Chapter 3
Introduction to Preferences Modeling: Context and Conventions

This chapter explains salient conventions in the field of Conflict Resolution and the practice of modeling preferences to add clarity to the manuscript included in this thesis as Chapter 4. First, Chapter 3 introduces the Graph Model for Conflict Resolution (GMCR) methodology, which is used to strategically analyze an environmental conflict in the manuscript included as Chapter 4. Aspects of the GMCR approach have informed the subsequent design choices implemented throughout this thesis. Many of the design features to be discussed in subsequent chapters are best understood after gaining familiarity with the GMCR approach. Next, this chapter addresses terminology that requires clarification because while it is common in Conflict Resolution scholarship, may not be shared with other fields of study concerned with environmental management. Finally, Chapter 3 discusses the practice of preferences modeling and situates this thesis within that scholarship.

The Graph Model for Conflict Resolution (GMCR) is an approach from the field of Conflict Resolution. It is a game-theoretic approach to modeling social conflict that has been applied to environmental contexts including, among others, sustainable development (Hipel & Obeidi, 2005), energy policy (Garcia, Hipel, & Obeidi, 2017; Xiao, Hipel, & Fang, 2015), water exports (Obeidi, Hipel, & Kilgour, 2002; Philpot, Hipel, & Johnson, 2016), aquaculture (Hamouda, Hipel, & Kilgour, 2004; Noakes, Fang, Hipel, & Kilgour, 2003), First Nations rights (Ma, Hipel, & De, 2005; Obeidi, Hipel, & Kilgour, 2006), and brownfield management (Hipel, Fang, Kilgour, & Haight, 1993; Hipel, Hegazy, & Yousefi, 2010; Walker, Boutilier, & Hipel, 2010; Yousefi, Hipel, & Hegazy, 2010). The manuscript included as Chapter 4 expands on previous work in GMCR by Hipel et al. (1993) by integrating new conflict developments into an updated conflict model.

Some conventions in terminology used in this area of study warrant a brief discussion. The term conflict is not restricted to violent or armed disputes but is defined broadly, being applicable to a variety of human interactions ranging from interpersonal disagreements, industrial competitions, negotiations, and national or regional wars (Xu et al., 2018). Any competitive interaction in which two or more decision-makers have their own goals, preferences, and power over options or actions can be modeled as a conflict. For example, the Elmira model included as Chapter 4 of this thesis is a conflict because there are more than two decision-makers, each with their own set of preferences over how the situation could be resolved and the ability to strategically control aspects of the situation to pursue the best outcome possible from their own perspective (Hipel et al. 1993).

The term decision-maker (DM) is used to describe an individual, organization, or entity that is involved in a dispute and has independent control over at least one option relevant to that dispute (Fang et al., 1993; Fang, Hipel, Kilgour, & Peng, 2003; Xu et al., 2018). In Conflict Resolution, a DM is distinct from a stakeholder as the latter can include individuals and entities who are impacted by the dispute whether or not they have any power over the outcome (Freeman, 1984). The term DM, as it is used in Conflict Resolution, does not imply any normative arguments about whether or not stakeholders should have power over decisions that impact them, nor does it imply that stakeholders do not have an important role in conflict situations. Distinguishing DMs from stakeholders simply facilitates the modeling of decision-maker power for analytic and interpretive purposes at a specific point in time.

GMCR can account for instances in real-world disputes in which a stakeholder may influence conflicts by taking actions outside of the formal decision-making context. For example, stakeholders may lobby decision-makers who have direct influence over the conflict outcome. This is captured in GMCR by modeling any subsequent changes to the formal DMs preferences that follow from stakeholder interventions. Alternatively, stakeholders may gain power over a decision option through activities outside of the formal decision context, transitioning from a stakeholder to a DM. In these cases, multiple models can be used to trace the evolution of the conflict thereby capturing these changes (Fang et al., 1993; Fang et al., 2003; Xu et al., 2018). The latter process occurred in the conflict described in Chapter 4. When Hipel et al. (1993) studied this conflict, a citizen advisory group had a limited advisory role and the same preferences as the local government, thus they were not modeled as a distinct DM. However, in the decades that followed the preferences between local government and the citizen advisory group diverged and the citizen advisory group also used an external grant to gain greater influence over the conflict. The manuscript in Chapter

4 presents an updated model that integrates these and other changes that occurred as the conflict evolved between 1989 and 2013.

As with any model, the representation of the conflict presented in Chapter 4 makes no claims to being definitive, nor is that the goal in including it in this thesis. Models are representations of aspects of a system or phenomena, necessarily omitting or generalizing information that is less relevant to the problem being addressed. When modeling complex, open, or evolving systems, the model builder chooses system boundaries; these boundary choices likely lead to uncertainties or inaccuracies in the model itself (Voinov, Seppelt, Reis, Nabel, & Shokravi, 2014). Nonetheless, the relationships which are captured become explicitly available for analysis, leading to the observation that "all models are wrong, but some are useful" (Box, 1979); with this in mind, one contribution presented in this thesis included as Chapter 4 is to illustrate why formal decision-modeling, while imperfect, can benefit researchers, decision-makers, and interested stakeholders who engage in environmental decision-making. The second contribution is to demonstrate specific techniques used in the GMCR approach that are extended into the later chapters.

Models are particularly useful when they make implicit assumptions explicit. For example, when using the GMCR approach, one of the first inputs required is the set of DMs. Each DM must be associated with at least one option over which they have autonomous control (Fang et al., 1993; Fang et al., 2003; Xu et al., 2018). Thus, as mentioned above, every DM must have real-world influence over the final decision outcome; this distinguishes stakeholders from DMs. The process of identifying DMs and options provides insights regarding the existing and perceived power distributions that characterize the conflict under study. Moreover, the process of including and excluding DMs within a model provides an auditable record of those power distributions, highlighting the constraints of the decision problem and perspective of the modeler. Whereas a GMCR model makes implicit power relationships explicit, in Chapters 6, 8, and 10 of this thesis, modeling is similarly used to make implicit assumptions about values and preferences explicit and auditable.

The following chapter illustrates the use of preference ranking to include DM preferences in the model. Various methods exist for including preferences in facilitated decision-making, many of which require participants to express their preferences as cardinal values known as utility values (Keeney & Raiffa, 1976; Robin et al., 2012). While these approaches can be useful in addressing problems that can be readily reduced to numbers, such as choosing among options that conserve specific acreages of wetlands or that involve expenditures in monetary terms, utility values can be difficult to elicit when more subjective, personal, or incommensurable factors are being evaluated (Fang, Hipel, Kilgour, & Peng, 2003; Xu et al., 2018). The GMCR approach improves on these techniques because cardinal values are not needed for modeling or analysis (Fang et al., 1993; Xu et al., 2018). As a consequence, non-quantitative evaluations of alternatives are sufficient to provide the ranked preferences needed to calibrate a model. It is much more intuitive for an individual to express their preferences in terms of 'more preferred', 'less preferred', 'greatly more preferred' or even 'equally preferred' to another option without being asked to ascribe a numerical value to each preference gap (Xu et al. 2018; Fang et al. 2003b; Fang et al. 1993). Chapter 4 describes a model that relies on such preference ranking setting the stage for the author's subsequent choice to integrate an adaptation of this approach into P2P-DSS. This manuscript is included as it was published in the Journal of Hydrological Research Letters (Philpot et al. 2017) including formatting conventions and the inclusion of a supplemental material section as required by that journal.

Chapter 4

Analysis of a Brownfield Management Conflict in Canada

This co-authored manuscript is included in this thesis as it was published in the Journal of Hydrological Research Letters in 2017.

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Simone L Philpot[1], Peter A Johnson[1] and Keith W Hipel[2,3,4]

[1]*Department of Geography and Environmental Management, University of Waterloo, Canada*
[2]*Department of Systems Design Engineering, University of Waterloo, Canada* [3]*Centre for International Governance Innovation, Canada*
[4]*Balsillie School of International Affairs, Canada*

Abstract:

A strategic analysis of an ongoing brownfield management conflict in Elmira, Ontario, Canada is conducted using the Graph Model for Conflict Resolution. This investigation of the situation as it existed in late 2016 constitutes an expansion of an earlier analysis of the dispute which focused on cleansing the groundwater aquifer, polluted by a chemical company in Elmira, to a controversy over the management of the pollution impacts on an adjacent creek. Besides the chemical plant, the other decision-makers involved in the 2016 dispute are the Ministry of Environment and Climate Change of the Province of Ontario, local government, and a citizens' advisory group. The connections of the 2016 conflict to the earlier study which took place in 1991 are discussed and the evolution of the previous situation to the current one is explored in depth, along with strategic insights.

KEYWORDS graph model; conflict analysis; water resources; brownfields

4-1.1 Introduction

Brownfield sites are unfit for most development activities due to environmental contamination that can threaten surrounding areas if not contained (Hipel, Hegazy, & Yousefi, 2010; Hipel & Walker, 2012; Walker, Boutilier, & Hipel, 2010). Industrialization is fueling the global creation of such sites, even as urban populations are growing, thus placing cities under increasing pressure to develop on or near contaminated lands (De Sousa, 2002; Hipel et al., 2010).

The challenges of managing brownfields can lead to conflicts regarding site remediation and the distribution of management burdens (Hipel & Walker, 2012; Kilgour, Chen, & Hipel, 2010; Walker et al., 2010). Greater understanding of management decision impacts is needed to generate socially acceptable processes and outcomes. In this study, the authors examine a brownfield management dispute in Elmira, Ontario, Canada. Aspects of this conflict were previously analyzed using the Graph Model for Conflict Resolution (GMCR) (Hipel, Fang, Kilgour, & Haight, 1993; Kilgour, Hipel, Peng, & Fang, 2001). The GMCR is used once again, to integrate emerging site issues and provide insights into the evolution of the Elmira conflict.

4-1.2 History of Water Contamination in Elmira, Ontario, Canada

Located in southern Ontario, Elmira was once known for its high quality and plentiful water. This resource attracted industry, bringing employment, as well as significant environmental and social costs (Baetz & Tanguay, 1998; Burtt, 2014a, 2014b). Of particular concern is a 35 hectares property in eastern Elmira that has been used for chemical operations for over a century. Notably, the pesticide dichloro-diphenyl-trichloroethane (DDT) was produced between 1948 and 1956, and continues to be a byproduct of manufacturing at the site. In the 1960s, the toxic herbicide Agent Orange was manufactured, producing a range of hazardous chemicals. The resulting waste materials were improperly disposed of and stored, thereby contaminating the land and aquifer underlying the property, as well as sediments in the nearby Canagagigue Creek (Baetz & Tanguay, 1998; Burtt, 2014a, 2014b; Dabrowska, Bates, & Murphy, 2012).

The site gained notoriety in 1989 when the discovery of N-Nirosodimethylamine (NDMA) at levels reaching 40 parts per billion (ppb) prompted the Ministry of Environment (MOE) to shut down two of Elmira's five municipal wells (Baetz & Tanguay, 1998). NDMA has a current maximum acceptable concentration (MAC) in drinking water of 0.04 ppb (The Government of Canada, 2011).

The owner of the land, Uniroyal Ltd. (UR) (now Chemtura), was identified as the source of this waste material (Hipel et al., 1993; Kilgour et al., 2001). Attention to environmental issues thus became galvanized around the site's impacts on the municipal drinking water supply. Under the Environmental Protection Act of Ontario *(1990-C. E.19)* the MOE issued a control order (CO) to UR in August, 1990. Parts of the control order were then appealed by UR. In October, 1991, the appeal process ended when the MOE and UR negotiated a management agreement that restricted UR's responsibilities only to restoring the municipal wells and protecting land off of the site from further impacts. Contamination of the Canagagigue Creek was not addressed. Local government and citizen groups objected to the agreement as they had been excluded from the negotiations, and it weakened the original control order (Baetz & Tanguay, 1998; Hipel et al., 1993).

Beginning in 1992, Citizen Advisory Groups were formed by the Provincial and Municipal governments to provide public oversight and input into the full spectrum of UR activities in Elmira (Baetz & Tanguay, 1998; Township of Woolwich, 2015b). Participatory processes ultimately failed to build trust between the stakeholders, and the citizen advisory groups have since been restructured several times throughout the conflict (Baetz & Tanguay, 1998; Township of Woolwich, 2015a). Nonetheless, many early members of advisory groups remain involved in monitoring the clean-up and management activities of the present owner of the land, Chemtura Ltd. (Baetz & Tanguay, 1998; Burtt, 2014b).

In spite of relative stability since the agreement's implementation, this conflict continues to evolve, recently driven by two factors. Firstly, the 1991 agreement did not address citizen concerns about the creek's water quality (Township of Woolwich, 2014a). Secondly, although an indemnity clause for known contamination restricts the MOE from issuing further control orders, an exception exists for new evidence relating to the extent or impact of the contamination (Kannon, 2015; Township of Woolwich, 2014b). Current activists are motivated to leverage this exception.

The citizen advisory group (CAG) at the time of this study, the Chemtura Public Advisory Committee, initiated the collection and analysis of ten samples from the Canagagigue Creek, upstream and downstream of the site (Township of Woolwich, 2015a). Elevated levels of contaminants, including dioxins, DDT and furans were discovered. These findings are supported by evidence from Chemtura's own 2011 testing, from earlier MOE initiated studies (Jaagumägi & Bedard, 1997), and from MOE testing in 2012 and 2013 (Township of Woolwich, 2014a). From the perspective of CAG, evidence of contamination beyond the scope of the initial control order opened a new regulatory option. CAG members called for ‘Action’ on the part of the MOECC to protect and restore the creek (Township of Woolwich, 2014a). The authors interpret this as escalating pressure on the MOECC to issue a control order compelling Chemtura to restore the Canagagigue Creek, as control orders are the regulator’s primary enforcement tool.

The Uniroyal site became Crompton Ltd. in 2001 and then Chemtura Ltd. in 2006 (CBC, 2015), with each successor required to adopt the responsibilities outlined in the control order (Township of Woolwich, 2011). The company could abandon the site, but only by declaring bankruptcy, which would require a prohibitive level of restructuring. This restriction does not, however, offer full protection to the other decision makers (Township of Woolwich, 2014c) as evidenced by bankruptcy filings initiated by Chemtura in the United States in 2009 (United States Bankruptcy Court Southern District of New York, 2003a, 2003b; US Attorney’s Office, 2010). In 2011 CAG and LG received assurances that if Chemtura pursues Bankruptcy, the MOECC will assume responsibility for managing the site (Township of Woolwich, 2011). This necessity, combined with the alternate possibility of a lengthy appeal process in response to regulatory actions, makes the MOECC highly unlikely to issue a new control order.

From the LG perspective, the risk of Chemtura abandoning the site is a concern, as 180 local jobs would be lost (Township of Woolwich, 2014c). Further, a judgement in the case of Kawartha Lakes (City) v. Ontario (MOE) (Court of Appeal for Ontario, 2013), ordered a municipality to pay for property contamination that was not the city’s fault.

4-1.3 Previous Research

The Graph Model for Conflict Resolution (GMCR) is a game-theoretic methodology used to model real-world conflicts (Fang et al., 1993; Fang, Hipel, & Kilgour, 1989; Kilgour, Hipel, & Fang, 1987). The method involves the identification of decision-makers (DMs), the set of options under the control of each DM, possible outcomes of the conflict, known as states, state preferences for each DM, and possible state transitions under the control of each DM. The model is analyzed for different types of stability, reflecting potential interactive human behavior under conflict. Unstable states will not endure but ones that are stable for all decision-makers will not change unless the conflict parameters are altered because the decision-makers receive no benefit from moving away from a stable state. The latter is an equilibrium and if it is reached during the dispute, may resolve the conflict. An equilibrium may be more or less desirable from the perspective of an individual decision-maker depending on their unique viewpoints. Thus, the fact that an equilibrium is likely to endure may represent a satisfactory resolution to one decision-maker but stagnation of the conflict to another.

A solution concept is a mathematically expressed description of possible human behavior under conflict that can be used to predict likely conflict outcomes (Fang et al., 1989). A given decision-maker is assumed to make choices that result in outcomes more preferable from his or her own perspective; however, different viewpoints, degrees of foresight and levels of risk aversion underlay decision-maker's evaluations. Thus, GMCR integrates a range of solution concepts into its analysis. One, Nash stability (Nash, 1950; Von Neumann & Morgenstern, 1944), describes situations in which a DM cannot unilaterally move the conflict from an initial state to a more preferred one. In contrast, a Nash unstable state exists if the DM can independently move the conflict to a more preferred state, via a unilateral improvement. If, however, a unilateral improvement can result in a counter move by another DM that is disadvantageous to the first DM and all unilateral improvements from the state are blocked in this fashion, the initial state is considered to be sequentially stable (SEQ) (Fraser & Hipel, 1984). Other solution concepts include General Metarational stability (GMR) (Howard, 1971) and Symmetric Metarational stability (SMR) (Howard, 1971). The combined results are used to characterize the overall conflict stability. A weak equilibrium describes a state which is stable by some, but not all solution concepts. A state which is Nash stable for all DMs is a strong equilibrium. A state is unstable if any DM can unilaterally move the conflict from a focal state to a more preferred state (Fang et al., 1993). Finally, a coalition can be used to reach a preferable outcome that is unavailable to a DM through unilateral actions, but achievable through cooperation with one DM or more. For example, in the Elmira case, the agreement that UR and MOE negotiated in 1991 (Kilgour et al., 2001) was only available through cooperative actions between the MOECC and Uniroyal, who considered this outcome advantageous.

Model development and analysis using GMCR has been operationalized by decision support systems including GMCR I (Fang et al., 1993), GMCR II (Fang & Hipel, 2003; Fang, Hipel, Kilgour, & Peng, 2003; Hipel, Kilgour, Fang, & Peng, 1997) and GMCR+ (Kinsara et al., 2015a). These software programs provide interfaces for building conceptual models of disputes, performing stability calculations, and interacting with models through stability and sensitivity analyses (Kilgour & Hipel, 2005).

Research by Hipel et al., (1993) initiated conflict analysis of the Elmira dispute using GMCR. The model focused on negotiations that occurred after UR had appealed the original control order (Hipel et al., 1993; Kilgour et al., 2001). The decision-makers included the MOE, Uniroyal Chemicals Ltd., and LG. At that time, CAG was not modelled as an independent decision- maker as its preferences were similar to LG's, and it had limited influence over formal decision making (Hipel et al., 1993; Hipel, Fang, & Kilgour, 2008). Hipel et al. (1993) identified nine states that could occur in this conflict. A stability analysis found three strong equilibria, including the agreement that occurred (Hipel et al., 1993, 2008). The model was then used for various illustrative and expansion purposes. Kilgour et al. (2001) integrated coalition analysis into GMCR, which was further expanded by Inohara & Hipel, (2008a, 2008b). The functional capabilities of GMCR II, were illustrated by Hipel et al. (1999) and by Hipel et al. (2008). Using fuzzy preferences and fuzzy option prioritization to model uncertainty in preference information was explored by Bashar, Kilgour, & Hipel, (2012, 2014). Clearly, the Elmira conflict study has inspired many graph model expansions, but the model itself has remained static.

4-2.1 Investigating the Elmira Conflict for 2016

This research calibrates an updated Elmira conflict model using materials from previous studies, as well as historic actions and statements recorded in the minutes of formal meetings and the media. The decision support system, GMCR+ (Kinsara et al., 2015a), used for the modeling and analysis, provides advanced analytical functions including stability analysis, sensitivity analysis, coalition analysis, inverse GMCR, and visualization functions (Kinsara et al., 2015a, 2015b).

Status of the conflict

At the time of model development, Chemtura and the MOECC have an agreement covering the remediation of the municipal aquifer. CAG is calling on MOECC and Chemtura to adopt more rigorous treatment strategies for DDT, dioxins and furans, along the Canagagigue creek.

Decision-makers and their options

Table 4-1 summarizes each decision-maker and the options it controls, with decision-makers and their respective options listed on the left, and the formal name of the decision-maker along with a brief description of each option on the right.

Table 4-1 Decision-makers and their options in the 2016 Elmira conflict investigation.

Decision-maker and their options	Description
MOECC	**Ontario Ministry of Environment and Climate Change**
1. Issue new CO	MOECC issues new CO related to Canagagigue creek management
Chemtura	**Chemtura Ltd**.
2. Delay	Chemtura delays through appeal of new CO
3. Accept	Chemtura accepts a new CO
4. Abandon	Chemtura files for bankruptcy
5. Volunteer	Chemtura volunteers to negotiate new clean-up measures
Local Government	**Regional Municipality of Waterloo and Township of Woolwich**
	Local Government escalates pressure for the issuance of a new CO
6. Escalate	
CAG	**Citizen Advisory Group**
7. Escalate	CAG escalates pressure for the issuance of a new CO

Note, that a new decision-maker, Citizen Advisory Group (CAG) has been added to the model to reflect the prominent role played by CAG as it has increasingly acted outside of a limited advisory capacity, by reaching out to media and initiating independent studies. In particular, CAG made recommendations to the MOECC that conflicted with government perspectives (Baetz and Tanguay, 1998). The designation CAG is actually a generalization that masks some complexity. In 1992 two citizen groups were established by the municipal and provincial governments. Over several years, internal disagreements between CAG and government entities resulted in splitting and restructuring of these groups. It was in the penultimate form, the Chemtura Public Advisory Committee, that CAG distinguished itself as a separate decision-maker. It is important to also acknowledge that private citizens were engaged in this conflict, outside of advisory groups, and influenced the preferences of CAG and LG. However, in a formal conflict model, a DM refers to an individual or entity with control over specific options in the dispute, rather than having an interest in the outcome, or influence over formal decision- makers.

Conflict States

A conflict with four decision-makers controlling a total of seven options has 128 (2^7) mathematically possible states, but not all are possible or likely to occur in practice. For instance, Chemtura cannot choose to simultaneously apply for bankruptcy and negotiate voluntary treatment measures; these options are *mutually exclusive,* and any states in which these options are jointly chosen are infeasible. Another kind of *infeasible state* that may be removed is one that is highly unlikely to occur, such as a state in which LG chooses to escalate the conflict after the MOECC has issued a control order. Issuance of a control order, by the MOECC to Chemtura, to compel management of the contamination at the Canagagigue Creek is the ultimate goal, and the primary source of conflict in this situation. Further, maintaining employment and the current financial arrangements outlined in the 1991 negotiated Agreement is important to LG, and could be at risk if Chemtura applies for bankruptcy. As such, it is reasonable to remove states in which the LG continues to escalate the conflict after this goal has been achieved. After all infeasible states are removed, eight states remain for analysis. These are shown in Table 3-2. The left column lists the decision-makers, and the options that each decision-maker controls. The section to the right shows the feasible states, listed as columns. Each of these columns is comprised of options that combine to form a state. For each option 'N' indicates that the decision maker controlling the option has not chosen it, while a 'Y' indicates that it has been selected. For example, at State 7, CAG has taken its option to escalate the conflict, LG has chosen not to escalate, and MOECC and Chemtura have not responded.

Table 4-2 Feasible States.

	Options	Viable States							
MOECC	1. Issue New CO	N	Y	Y	Y	N	N	N	N
Chemtura	2. Delay	N	Y	N	N	N	N	N	N
	3. Accept	N	N	Y	N	N	N	N	N
	4. Abandon	N	N	N	Y	N	N	N	N
	5. Volunteer	N	N	N	N	Y	N	N	N
Local Government	6. Escalate	N	N	N	N	N	Y	N	Y
CAG	7. Escalate	N	N	N	N	N	N	Y	Y
State number		1	2	3	4	5	6	7	8

State Transitions

When a decision-maker can independently move the conflict from one state to another state, he has an available *unilateral move*. For instance, LG can move the conflict from State 7 to State 8 by changing its option selection from 'N' to 'Y', whereas the options selections of the other decision-makers remain fixed. By this choice, LG escalates the conflict in cooperation with CAG. Once selected, some options can be reversed by the decision-maker. For instance, LG can stop escalating the conflict, thereby moving from State 8 back to State 7. Other option choices are considered *irreversible*, such as Option 1 in which MOECC issues a new control order, Option 3, in which Chemtura accepts a control order, and Option 4 in which Chemtura claims Bankruptcy.

Decision-maker's Preferences

Decision-maker preferences and their rankings of states are based upon evidence of preferences as recorded in the minutes of formal meetings, media statements, and previous actions of each decision-maker, which have been referenced in previous sections of this text. The authors also benefitted from communication with an expert on this conflict. The authors then used a flexible method of inputting preferences that is available when using GMCR+; this method is called option prioritization (Hipel et al*.,* 1997; Fang et al., 2003a, 2003b). It allows relative preferences to be input using logical preference statements about option selections. These statements are used to sort states from most to least preferred, including ties, based on the decision- maker's preference statements for specific options. Preference statements used to calibrate this model are provided in Table S3-2, with most important at the top and less important at the bottom for a given decision-maker. A relative preference ranking of states is then generated for each decision-maker. The preferred states for the MOECC, ranked from most to least preferred are (1,5) 3,7,6,8,2,4. States in parentheses are equally preferred. Following the same conventions, Chemtura's are 1,7,6,8,2,4,5,3; LG's are (3,5)1,(6,7,8),2,4; and CAG's are 3,5,4,2,8,7,6,1.

Stability Analysis

Analysis reveals five equilibria, including States 2,3,4,7 and 8, whereas States 1, 5, and 6 are unstable. State 3 is highly preferred by MOECC, LG and CAG, but it is controlled by Chemtura, for which it is a least preferred state. Thus, State 3 is unlikely to occur. States 2 and 4 are similarly controlled by Chemtura. Although CAG and LG control states 7 and 8, this offers little advantage in the real-world dispute, as they are not highly preferred states for these decision- makers. Application of solution concepts is shown in tableau format (Fraser and Hipel, 1984) in Table 3-3. Each decision-maker is shown with the states ranked from most preferred to least preferred, from its own perspective. Unilateral improvements are listed underneath each state, for each decision-maker. Above each state its stability is indicated by an 'r' for Nash stability, an 's' for SEQ stability, and a 'u' for unstable. Overall stability is then indicated by 'E' for states in equilibrium, or 'X' for unstable states. To illustrate this process, consider State 2, which has no unilateral improvements listed under it for any decision-maker. Thus, State 2 is Nash stable for all decision-makers and is in equilibrium. By contrast, consider state 6. LG has a unilateral improvement from State 6 to State 1. From State 1, CAG can move the conflict to State 7. Because LG prefers state 7 less than State 6, State 6 is SEQ stable for LG. This process is illustrated in Table 4-3*,* for which Y-N notation is used. Note that in the unilateral improvement from State 6 to State 1, only LG's strategy changes. Similarly, only CAG changes its strategy in response.

Sensitivity Analyses

Through sensitivity analyses it is possible to explore 'what if' questions. The authors entertained the question: *"What if the MOECC was more sensitive to public pressure?".* To reflect this, the preference ranking of MOECC was adjusted to (1,5) 3,7,6,2,4,8. This resulted in no change to the earlier stability findings. To probe the role of public pressure over the conflict outcome, an analysis was then conducted to ask *"What if Chemtura were more sensitive to conflict escalation?"*. The Chemtura preferences were altered to 1,5, (7,6,8), 2,4,3. State 5 consequently changed from being unstable to a weak equilibrium. In this scenario, a state transition from 5 to 1 can be sanctioned by the CAG moving from State 1 to State 7.

Table 4-3 Application of Solution Concepts in Tableau Format. Lines placed under states indicate that the states are equally preferred for the focal DM. Overall states stability is indicated by an 'E' for equilibrium or an 'X' for unstable. Individual DM stability.

								MOECC
X	X	E	E	X	E	E	E	Overall Stability
r	r	r	r	r	r	r	r	DM stability
1	5	3	7	6	8	2	4	DM preference Vector
								UIs
								Chemtura
r	r	r	r	r	r	u	r	DM stability
1	7	6	8	2	4	5	3	DM Preference Vector
						1		UIs
								Local Government
r	r	r	s	r	r	r	r	DM stability
3	5	1	6	7	8	2	4	DM Preference Vector
			1					UIs
								Citizen Advisory Group
r	r	r	r	r	r	u	u	DM stability
3	5	4	2	8	7	6	1	DM Preference Vector
						8	7	UIs

Finally, an analysis was performed to ask *"What if the LG and CAG were more resistant to escalating the conflict?"*. The preference rankings for LG and CAG were both altered to (5,3) 1 (8,7,6) 2,4. In this scenario, State 6 is a weak equilibrium that is unstable for LG because it has the ability to transition to State 1. Similarly, State 7 is unstable for CAG whereas State 1 is stable. Hence, if the LG and CAG were less inclined to escalate the conflict, the dispute would be more likely to reach and to remain at State 1, in which no conflict escalation occurs.

4-2.2 Evolution of the Elmira Conflict

Table 4-4 shows this conflict's evolution from the previous to the current model. The model developed by Hipel et al. (1993), addressing contamination of the Elmira municipal aquifer, is displayed on the left. Arrows indicate a change in option choice, which causes a change in state, when reading from left to right. For example, under 1991 Status Quo, LG alters its option choice, resulting in a change of state. Further changes, also illustrated by arrows, move the conflict into a cooperative equilibrium. The progression from the cooperative equilibrium to the current model, 2016 Status Quo, is shown on the right.

Table 4-4 Evolution of the Elmira conflict. The left side of the table shows the model developed by Hipel et al., (1993) addressing NDMA contamination of the Elmira municipal wells. The option 'Modify' refers to modification of a CO for treatment of aquifer contamination. Arrows show changes in strategy that result in conflict evolution. The current conflict status is shown to the right of the table. "Issue new CO" refers to a CO related to management of contamination impacting the Canagagigue Creek.

Decision makers and their options	1991 Status Quo	Non-cooperative Equilibrium	Cooperative Equilibrium	Updated decision makers and their options	2016 Status Quo
MoE				**MOECC**	
1. Modify	N	N	→ Y	→ 1. Issue new CO	N
Uniroyal				**Chemtura**	
2. Delay	Y	Y	→ N	2. Delay	N
3. Accept	N	N	→ Y	→ 3. Accept	N
4. Abandon	N	N	N	4. Abandon	N
				5. Volunteer	N
Local Government				→ **Local government**	
5. Insist	N	→ Y	Y	6. Escalate	N
				→ **Citizen Advisory Groups**	
				7. Escalate	Y

4-2.3 Discussion of Stability Analysis Results

Currently, the most-preferred options for LG and CAG are controlled by Chemtura, a situation that holds true for the stability analysis, and for each scenario explored through sensitivity analyses. This situation highlights an important power asymmetry in the dispute: Chemtura dominates the conflict because of a lack of important options under the unilateral control of the other decision-makers.

The sensitivity analyses indicate that had both LG and CAG been less inclined to escalate the conflict, the dispute would likely have reached and remained at State 1, wherein no conflict options are taken. Thus, early attention to CAG's concerns in relation to broader site issues, specifically to the quality of the Canagagigue Creek, might have produced a more-enduring equilibrium. These findings reflect those of Walker et al., (2010) in their analysis of a successful brownfield redevelopment project in Kitchener, Ontario, Canada. Both studies highlight the importance of the quality of the working relationships between conflicting decision-makers in successfully managing brownfield sites. Text S2 provides further discussion highlighting some aspects of the research findings in the context of brownfield management in Ontario, Canada.

4-3. Conclusions

By revisiting the ongoing water management conflict in Elmira, Ontario, Canada, using the Graph Model for Conflict Resolution, this investigation has expanded upon the earlier analysis of the dispute, which was completed in 1993 (Hipel et al., 1993). By tracing the connections between the groundwater conflict that was investigated in 1993, and enduring concerns over contamination of the Canagagigue creek, an updated model of the evolution of the dispute has been generated. Important parameters that have been updated include the recognition of a new decision-maker, identification of a new option available to the MOECC, and the development of a formal representation of the evolution of this conflict. This updated model of the Elmira water contamination conflict provides opportunities to better understand the situation, and for future research to explore new avenues for reaching an enduring and socially acceptable resolution. For instance, while an equilibrium indicates an outcome that is likely to endure if it is reached, any equilibrium state may be more or less acceptable according to the perspective of a single decision- maker. In the Elmira dispute, dissatisfaction with the equilibrium reached in 1991 contributed to efforts by CAG to change the model parameters, resulting in the conflict evolution presented herein. Conflict analysis techniques can support decision-makers as they seek outcomes that are more preferred by all parties. One option is found in a recent extension to GMCR, the Inverse Approach to the Graph Model of Conflict Resolution (Kinsara et al., 2015b), which facilitates identifying preferences a target decision maker should adopt to reach a specified outcome. This information can be used to motivate decision-makers to take preferable actions to work towards mutually beneficial outcomes (Kinsara et al., 2015b).

Conflict models can also facilitate negotiations by supporting the development of common perspectives of the situation (Okada & Sakakibara, 2004); clarifying the diverse, and often conflicting interests and viewpoints, of different decision-makers; identifying trade-offs; and collaboratively generating solutions that integrate multiple preferences (Yousefi, Hipel, Hegazy, Witmer, & Gray, 2007). By explicitly addressing and dealing with conflicting objectives, decision-makers can more clearly discuss and reach mutual agreements and socially acceptable outcomes (Yousefi et al., 2007). Along these lines, the utilization of GMCR for third party negotiations has shown that a coordinator or other third-party negotiator can use these models to facilitate communication with multiple decision-makers (Hipel, Sakamoto, & Hagihara, 2015). Finally, participatory modeling using GMCR can reduce the risks of misunderstandings during the negotiation process (Okada and Sakakibara, 2004). Decision-makers with shared understandings of the conflict may develop mutual agreements that bypass the need for prolonged appeals, and conflicts that delay site remediation. Specific to the Elmira conflict, this updated model aims to clarify the evolution and current status of the situation, and to facilitate the future application of innovative conflict resolution strategies.

4-4.1 Supplemental Material

Text S3-1. List of abbreviations

CAG	Citizen advisory group
CO	Control order
DM	Decision maker
GMCR	Graph Model for Conflict Resolution
LG	Local government
MOE	Ministry of Environment
MOECC	Ministry of Environment and Climate Change
SEQ	Sequentially stable
UI	Unilateral improvement
UR	Uniroyal

Text S4-2. Discussion of brownfield management in Ontario, Canada

Canada is estimated to have about 30,000 brownfield sites (*Federation of Canadian Municipalities. 2009. Brownfields sustainability snapshot Green Municipal Fund*, 2017). Their management and redevelopment reduce environmental and public health risks, while encouraging significant economic benefits when the land is returned to productive uses. However, the social and technical costs of remediation can deter investment in this process, and can make land owners resist actions that may result in increased regulatory oversight of their activities (Yousefi et al., 2007). Better understanding of ways to achieve acceptable management outcomes, from the perspective of multiple decision makers, may encourage greater use of these lands and decrease delays that can result in contamination remaining untreated (Yousefi et al., 2007). This section summarizes important insights raised in the conflict analysis, and explores key policy and methodological implications.

It is first important to acknowledge some limitations in generalizing from this conflict analysis to other environmental controversies. First, while many brownfield negotiations are initiated due to perceived opportunities for development of the land, the Elmira conflict was instigated because of the health and environmental impacts that poorly managed contamination had upon the neighboring community. The immediate risk to public health provided the impetus to civic involvement, but such a motivation may not arise in negotiations to purchase other brownfield sites for development. Further, members of the public who became involved in the citizen advisory groups in Elmira had a strong capacity to engage with the highly technical information required to understand the impacts of the contaminants and proposed remediation plans, and to communicate with the corporate and regulatory stakeholders. This capacity translated into a dynamic "activist elite" that remained engaged in the conflict for several decades (Warriner, Madden, McSpurren, & Lukasik, 1996). This strong social capital combined with a long history of leadership in groundwater protection that characterizes the Regional Municipality of Waterloo indicate a need for caution in making generalizations to other cases in Canada or internationally (Ivey, de Loë, & Kreutzwiser, 2006). Nonetheless, this conflict can facilitate discussion regarding the localization of decision-making in brownfield management, and its place within broader efforts for source water protection.

Brownfield management is an important factor in source water protection. Within Ontario, water source protection is implemented by municipalities; however, decision-making authority rests with provincial regulatory entities (Ontario 2004; Ivey et al*.,* 2006). Historically, provincial regulatory bodies have preferred to negotiate with the polluter (Ivey et al., 2006). With their legislative influence over water source protection rooted in control over land-use planning, municipal influence is particularly restricted when dealing with existing sites of concern (Ivey et al., 2006). In the Elmira case, for instance, LG lacked authority to require contaminant clean-up because a planning application was not required (Ivey et al., 2006). In spite of recommendations in 2004 for new legislative tools and regulatory authority for municipalities to address existing threats to source waters, this objective has not been effectively implemented (Ontario, 2004; Ivey et al., 2006). With this in mind, it is worth noting that when municipal tools have been relevant, the ability of local governments to influence negotiations has led to the timely development of mutual management agreements (Yousefi et al., 2007). Thus, extending local authority to instances where existing contamination poses a risk to public health and environmental security could promote more effective negotiations at the local level by addressing the asymmetry in decision-making power noted in this analysis.

Finally, the role of public participation in environmental decision-making plays a key role in the Elmira conflict. Informal networks were leveraged by the citizen advisory groups, demonstrating the importance of governance structures outside of formal networks. The role of public pressure and perception means that attention to formal roles in decision-making processes may not capture important opportunities for conflict evolution. Better integration of citizens' perspectives and values during initial negotiations may have produced an agreement that led to a more robust equilibrium. This missed opportunity is related to the importance of public values in water management practice and research.

Figure S4-1 Map of Elmira, Ontario, Canada.

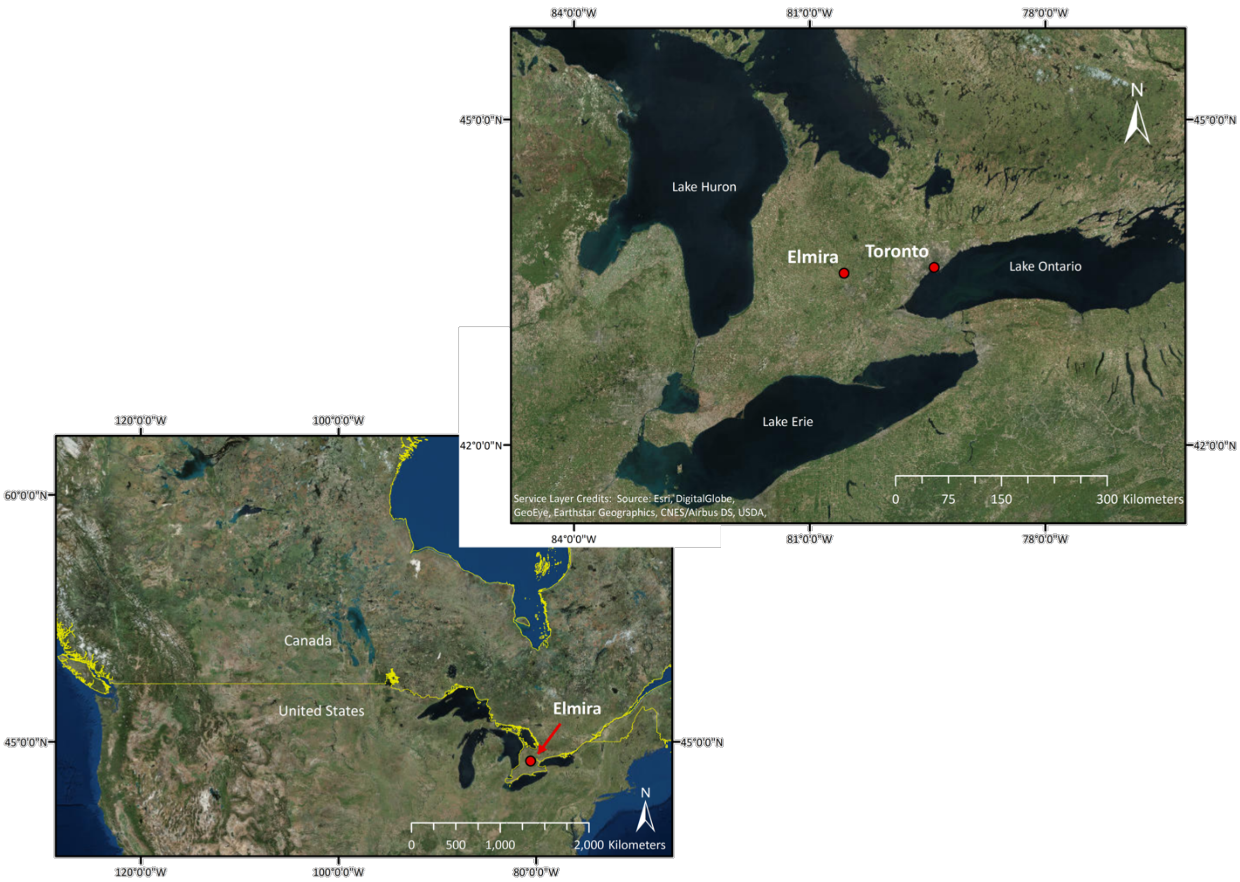


Table S4-1 Definitions of Solution Concepts (based on Fang et al. (1993)).

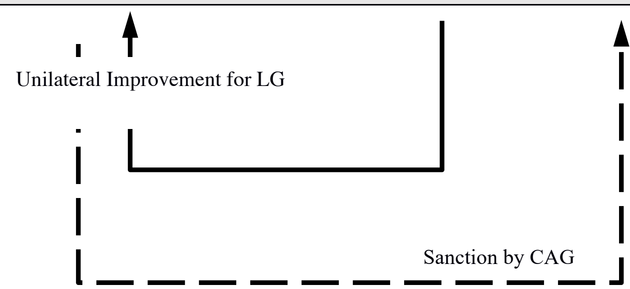
Solution Concepts	Stability Descriptions	Unilateral Improvements
Nash (R)	Decision-maker (DM) *i* expects his or her own move to be the final move. Potential countermoves by the other DMs are not considered.	DM *i* has no unilateral improvements.
General Metarationality (GMR)	DM *i* expects another DM to sanction DM i's move if it is possible. DM *i* only anticipates this one responses, he or she does not anticipate subsequent moves.	Any unilateral improvements available to DM *i* can be sanctioned by a subsequent move by another DM.
Symmetric Metarationality (SMR)	DM *i* expects another DM to sanction DM *i*'s move if possible and anticipates responding to such sanctions. The counter response of *i* is perceived as the end of the sanctioning.	Any unilateral improvements available to DM *i* can be sanctioned by a subsequent move by another DM and DM *i* cannot respond favorably to a sanctioned move.
Sequential Stability (SEQ)	DM *i* anticipates that another DM can levy a unilateral improvement that is less preferred from the perspective of DM *i*.	DM *j* can take advantage of a unilateral improvement to the disadvantage of DM *i*.

Table S4-2 Preference statements used in the 2016 Elmira conflict investigation. Preferences are listed from most important at the top to least important at the bottom for each decision-maker.

Decision-maker	**Preference statements from most important at the top to least important at the bottom**
Ministry of Environment and Climate Change (MOECC)	Most prefers that Chemtura does not abandon the contaminated site. Then prefers that Chemtura does not appeal a new CO. Prefers that the local government does not escalate their pressure on the MOECC Prefers that CAG does not escalate their pressure on the MOECC. Next prefers not to issue new CO. If MOECC issues a new CO, it prefers that Chemtura accepts it.
Chemtura	Most prefers not to accept a new CO. Prefers not to voluntarily increase or alter its current treatment regime. Next prefers not to abandon the site through Bankruptcy. Prefers not to launch an appeals process. Then prefers that LG and CAG do not escalate the conflict together. Next prefers that LG does not escalate the conflict Prefers that CAG does not escalate the conflict.
Local Government (LG)	Most prefers an accepted CO or voluntary actions by Chemtura. Next prefers that Chemtura not abandon the site through bankruptcy. Prefers that MOECC and Chemtura do not engage in an appeal process. Prefers not to escalate the conflict and prefers CAG does not escalate the conflict.
Citizen Advisory Group (CAG)	Most prefers that the MOECC issue a CO for the creek and it is accepted by Chemtura. Next prefers that Chemtura voluntarily address concerns related to the Canagagigue creek. Prefers any state in which a new CO is issued. Next prefers to escalate pressure on the MOECC and Chemtura with support from LG. If a new CO is issued, CAG prefers that Chemtura does not appeal. Prefers to escalate the conflict until treatment is increased by CO or voluntary changes.

Table S4-3 Process of move and countermove in Sequentially stable State 6.

	Option	States		
MOECC	1. Issue New CO	N	N	N
Chemtura	2. Delay	N	N	N
	3. Accept	N	N	N
	4. Abandon	N	N	N
	5. Volunteer	N	N	N
Local Government	6. Escalate	N	Y	N
CAG	7. Escalate	N	N	Y
State number		**1**	**6**	**7**



Chapter 5
Introduction to Values-based Decision-making and The Design of P2P-DSS

This chapter introduces concepts from the field of Decision Sciences that are relevant to the study and implementation of values-based decision-making. This chapter also provides a brief introduction to the benefits and challenges of values-based decision-making that drive the work to be presented in Chapter 6. In so doing, Chapter 5 aims to highlight the contributions of the research presented in Chapter 6 to the fields of Decision Sciences and Environmental Studies.

Values are of interest to the fields of Decision Sciences (Keeney & McDaniels, 2001; Parnell et al., 2013; Wenstøp & Koppang, 2009) and Environmental Studies (Daw et al., 2015; Drescher, 2014; Groenfeldt & Schmidt, 2013; Medina, 1993). Many benefits from focusing on values when making decisions have been documented in a range of contexts including homeland security decision-making in the United States government (Keeney & von Winterfeldt, 2011), risk reduction among teenagers and young adults (Keeney & Palley, 2013) and environmental decision-making (Morais, Alencar, Costa, & Keeney, 2013; Reid et al., 2014). While, these benefits will be discussed in detail in Chapter 6, overall, this body of scholarship indicates that focusing on values during decision-making improves the process and outcomes of decisions from the perspective of formal decision-makers and public participants (Arvai, Gregory, & McDaniels, 2001; Gregory & Keeney, 2002; Parnell et al., 2013).

One challenge to expanding the reach of values-based decision-making techniques is their reliance on skilled facilitators and in-person workshops. To date, only a limited number of efforts have been made to expand the reach of these techniques by using computer facilitated decision support system techniques in participatory settings (Bessette et al., 2016). One of the reasons these efforts are challenging is that values are difficult to articulate, thus, thinking through ones values benefits from structured in-person facilitation such as value-focused workshops (Keeney, 1992; Keeney, 2004; Parnell et al., 2013). This reliance on structured, facilitated processes is important because a limited number of people can participate in each workshop, participants are required to learn unfamiliar techniques in order to participate, and local governments may lack the budget to pay for professional facilitation. Thus, these techniques may remain inaccessible in many situations where they could be useful (Bessette et al., 2016). Facilitating values-based thinking using software programs that can be delivered by email or hosted online, similar to online surveys, may make values-based approaches more accessible, but the required computerization and loss of a skilled facilitator is not a trivial change. Thus, operationalizing values in a software modeling environment may affect the quality of the value-focused process. In examining this problem, one of the research questions driving this research is *"*How can one operationalize values-based decision-making for enhancing environmental management?" To respond to this question, the research presented in Chapter 6 proposes that applying the theory of *values activation* (Grube et al., 1994; Rokeach, 1968), from the field of personality and social psychology, may provide opportunities to facilitate values-based decision-making using interactive software.

A review of past literature reveals that values-based thinking can be prompted in experimental conditions when participants are given feedback about how their own values compare to the values of others (Hosack, 2007; Rokeach, 1968), and that this process can lead to changes in choices and behaviors (Verplanken & Holland, 2002), and be used to guide participants to make choices that are more congruent with their own values (Hosack & Paradice, 2014). This method, known as Value Self-Confrontation (Grube et al., 1994; Rokeach, 1975), is used to induce a state of dissatisfaction, also known as cognitive dissonance (Festinger, 1962), or satisfaction in participants by confronting them with feedback about their own values and those of others (Grube et al., 1994; Rokeach, 1975). The resulting impact of values confrontation can activate values, bringing them into awareness and increasing their influence in the decision-making process (Grube et al., 1994; Schwartz, 2017; Schwartz, 2012). The research presented in Chapter 6 is the first such study that uses an interactive visual representation of the participants own values to cause values activation. Chapter 6 situates this dissertation within facilitated values-based thinking scholarship while also highlighting the connections between this dissertation and online participatory environmental decision-making.

Chapter 6

Proposal, Design and Evaluation of a Values-centric Decision Support System

The following chapter is comprised of a manuscript currently submitted for journal review and publication. This co-authored manuscript is included in this thesis as it was submitted.

Philpot S.L.[a], Philpot C.T.[b], Hipel K.W.[cde], Johnson P.A.[a] 2019. Submitted Manuscript. Department of Geography and Environmental Management and Department of Systems Design Engineering, University of Waterloo, Canada.

Philpot S.L.[a], Philpot C.T.[b], Hipel K.W.[cde], Johnson P.A.[a] 2019.
[a] Department of Geography and Environmental Management, University of Waterloo, Canada.
[b] Application Developer.
[c] Department of Systems Design Engineering, University of Waterloo, Canada.
[d] Centre for International Governance Innovation, Waterloo, Canada.
[e] Balsillie School of International Affairs, Waterloo, Canada.

Abstract:

A novel values-based participatory modeling tool for enhancing environmental management is developed and tested. The software program, Public to Public Decision Support System, operationalizes the theory of values activation to enhance the process of providing online public input by prompting users to engage in values-based decision-making. User evaluations of the Public to Public Decision Support System are collected in a written post-task survey. Responses indicate that using this system makes the connections between preference rankings and values explicit. Moreover, based on user evaluations, the approach facilitates the collection of input that is consistent with user values and some users report spending more time and effort seriously considering their responses. Thus, this study proposes, implements and evaluates a prototype version of a novel method for activating values using interactive modeling in a participatory decision support system and discusses the potential impact this approach may have for online participation in environmental management.

KEYWORDS values; decision support systems; participatory modeling; e-participation

6-1.1 Introduction

Existing research indicates that people are more satisfied with decisions that have been reached after values have been explicitly examined as part of the evaluation process (Gregory & Keeney, 2002; Keeney, 1992; Keeney, 2004; León, 1999; Parnell et al., 2013). Typically, values-based approaches guide participants through a process of problem framing, identifying and organizing specific objectives, creating alternatives, identifying consequences, and analyzing trade-offs (Keeney, 1992). While these steps have well-researched benefits in terms of managing the negative impacts of heuristics employed in decision-making, this structured approach also entails significant barriers in terms of cost, time constraints, and access to skilled facilitators (Bessette et al., 2016; Parnell et al., 2013). These costs may be justifiable for some decision contexts, but they can also limit access to values-based decision-making. This research examines opportunities to reduce those limitations by proposing a new approach to integrating values-based thinking into computerized decision support.

This work proposes a new method for facilitating computer aided values-based thinking using the theory of values activation (Grube et al., 1994; Rokeach, 1968). The importance of this work for participatory environmental decision-making is presented in this introduction. First the authors discuss the role of *e*-participation in environmental decision-making. The authors then examine the relevance of online decision support systems in integrating human dimensions of decision-making. Next, this paper includes a review of the theoretical foundations underpinning values activation (Grube et al., 1994; Rokeach, 1968). The authors then describe the design and implementation of the Public to Public Decision Support System (P2P-DSS), a participatory modeling program developed in the course of this research that uses the theory of values activation to operationalize values. This paper presents design elements that govern the behavior of P2P-DSS including the process of using the software system to build a values-centric model of a decision problem and subsequent use of that model to collect user preferences. Finally, the authors discuss user responses to post-task evaluation surveys which are used to evaluate the effectiveness of the DSS and to gain insights into the user experience.

The remainder of section 1 explores three areas of scholarship that informed this research: e-participation, decision support systems, and values in decision-making. Section 6-

2 examines past and current approaches to integrating social values into participatory decision-making. Section 6-3 outlines the theoretical foundations and design elements underlying P2P-DSS. Section 6-4 presents a real-world application of P2P-DSS. In Section 6-5 research findings are provided and discussed. Finally concluding thoughts are included in Section 6-6.

6-1.2 E-participation and Government Decision-making

Democratic governments are frequently required to consult with the public, but collecting and integrating public input on complex decisions pose significant challenges. Responding to public input can improve relationships between citizens and decision-makers, reduce conflict, and result in policies that better reflect citizen priorities (Irvin & Stansbury, 2004; Mostert, 2003). However, these improved outcomes can only be realized if citizens are able to understand the likely outcomes from competing alternatives, articulate their own preferences, and effectively deliver them to formal decision-makers; success in these criteria typically requires robust, formalized decision-making processes (Sahin, Mohamed, Warnken, & Anisur, 2013).

The social and technical complexity that typifies environmental and development issues can make citizens and public decision-makers hesitant to participate (Warriner et al., 1996). For instance, the scientific complexity of environmental issues can reduce the confidence that managers have in the quality of public opinions and the trust that non-expert citizens have in the validity of their own input (Gregory, Fischhoff, & McDaniels, 2005; Mostert, 2003). For example, two years after residents in Toowoomba, Australia, voted against indirect potable wastewater reuse in a hotly contested referendum, the Premier of Queensland, viewing this as a poor outcome and threat to the implementation of effective water source solutions, announced that water recycling in Brisbane would be implemented without a public referendum (Hurlimann & Dolnicar, 2010; Ross, Fielding, & Louis, 2014). When participatory processes fail, the costs can be significant, but even more costly is the potential heightened cynicism towards government and regulatory bodies, participation fatigue, increased conflict, and lost opportunities to improve decision-making (Carr et al., 2012; Gregory et al., 2005; Nabatchi, 2012; Reed, 2008).

In spite of the challenges, the expected benefits of participation mean that regulatory and government entities are required to integrate public input into their decision-making at international (UN-ECE (United Nations Economic Commission for Europe) AARHUS Convention, 1998) and domestic (Hillier, 1999) levels of government (Irvin & Stansbury, 2004). Advancements in Information and Communications Technology (ICT) offer new ways to engage in participatory processes and they are therefore increasingly being adopted by municipalities and government agencies (Afzalan, Sanchez, & Evans-Cowley, 2017).

Electronic participation (*e*-participation) techniques use ICT to mediate dialogues between citizens and decision-makers to facilitate timely and effective public participation in governmental spheres (Porwol, Ojo, & Breslin, 2016). Many e-participation tools recreate forms of participation that are similar to off-line contexts, having been practiced in real-world settings before the proliferation of online web tools and recent increases in internet accessibility. For example, web features that allow citizens to directly email their representatives through a municipal website are analogous to accepting physical letters to be read for consideration. Another illustration is the replacement of survey and opinion polls delivered by mail with online opinion surveys distributed through social media or hosted on government websites; in this case, the role of ICT is to increase the efficiency of the participatory act rather than to transform the services available in a meaningful way. While these options play an important role in reducing the effort required to provide input for some citizens, and in helping government entities to reach their service delivery goals, e-participation is capable of much more innovation in the form of adding services that are not readily achievable or accessible in real-world settings and engaging a greater variety of citizens to contribute their perspectives (D ’agostino, Schwester, Carrizales, & Melitski, 2011; Lourenço & Costa, 2007). By implementing decision-support elements within E-participation platforms, new ways of bridging the gap between citizens, experts and formal decision-makers become available.

e-Participation approaches are not universally inclusive. However, as internet technologies become ubiquitous, it is reasonable to presume that familiarity and ease of use will increase. In 2016, the Canadian Radio-television and Telecommunications Commission (CRTC) recognized high speed internet as a basic service that is necessary for quality of life. Implementation of this recognition should result in 90% of Canadian homes and businesses having access to high quality broadband (Canadian Radio-Television and Telecommunications Commission (CRTC)). Reduction in the digital divide (Browning, 2002) will make online methods of civic engagement increasingly important, particularly for citizens in remote regions who wish to find a voice in both local and non-local political decision-making, adding urgency to efforts to develop and evaluate the impacts of a full class of online participation approaches (French, Insua, & Ruggeri, 2007).

6-1.3 Decision Support Systems

Decision support refers to a process used to help a person or groups to collect relevant information and to generate and evaluate decisions (Recio-García, Quijano, & Díaz-Agudo, 2013). Decision Support Systems (DSS) are software enabled tools used to provide decision support by collecting and organizing information for calibrating models to analyze situations for aiding in formal decision making. DSSs operationalize theoretical methods in a user-friendly way for researchers, experts and non-expert users alike (Kinsara et al., 2015a; Sage, 1991).

Frequently applied in water resources management (Mysiak et al., 2005), a growing number of DSS now support the modeling and analysis of social and physical dimensions of decision-making (Hipel et al., 2008; Hipel, Fang, & Kilgour, 2002). For example, in conflict analysis, DSS are used to explore resolutions to contentious multiple decision-maker controversies, with an emphasis on modeling preferences and anticipating strategy choices based on personality traits (Fang & Hipel, 2003; Fang et al., 2003; Hipel, Kilgour, Fang, & Xiaoyang, 1997; Xu et al., 2018). Recio-García et al., (2013) developed a recommender tool that integrates social factors such as personality and trust into a group DSS. The MULINO DSS (*m*DSS) tackles complex watershed management problems by operationalizing the DPSIR (driving force-pressure-state-impact-response) as a framework to evaluate the performance of alternatives against a model, based on user preferences (Mysiak et al., 2005). Labiosa et al., (2013) apply a multi-criteria model-based framework, The Ecosystem Portfolio Model, to integrate stakeholder quality of life indicators and preferences into integrated land-use assessments. Finally, integrated modeling platforms are increasingly used to support policy-making and the acceptability of policies in terms of linked environmental and socio-economic factors (Hamilton, Elsawah, Guillaume, Jakeman, & Pierce, 2015). While this is not an exhaustive list, it illustrates that DSSs have evolved from their early focus on physical environmental processes, and have an important role to play in support of integrating the human dimensions of environmental decision-making (Hipel et al., 2008; Hipel et al., 2002; Mysiak et al., 2005).

6-1.4 Values in Decision-making

Values are a contested concept across disciplines and are often conflated with other motivational factors; thus integrating values in decision support requires an agreed understanding of what values are and how they influence decision-making (Hitlin & Piliavin, 2004). In this research, the authors draw largely upon the body of work built by Schwartz & Bilsky, (1987) and Schwartz, (1992), and continued by various researchers in psychology and sociology. Overall, the description of values from this area of study is paraphrased as follows: values are trans-situational beliefs linked to goals with positive associations which are ranked by importance, serve evaluative functions, and motivate the specific behaviors to which they are related. When an individual considers a value to be important they are motivated to pursue goals that support that value (Hitlin & Piliavin, 2004; Prince-Gibson & Schwartz, 1998; Rohan, 2000; Rokeach, 1968; Schwartz, 2012).

Values are more effectively engaged in decision-making when they are activated, that is when those values are made the focus of conscious attention, as when an important or central value is threatened, or when an opportunity to support a highly prioritized value arises (Verplanken & Holland, 2002). When values are activated, a decision-maker may be compelled to make increasingly values-congruent decisions. These are decisions or assessments that are consistent with the values framework of the individual or group making the decisions (Verplanken & Holland, 2002).

Because values activation can lead to more values-congruent decision outcomes, techniques to activate values for facilitated decision-making have been developed and become the subject of scholarly research. For instance, Stern & Dietz, (1994) identify increased pro-environmental behavior when highly valued environmental conditions are threatened. Verplanken & Holland, (2002) encouraged pro-environmental decision-making by activating values-based thinking using priming manipulations. In the latter case, simply having participants read and think about specific values was sufficient to activate values, and thus to encourage value-congruent choices. Values-congruent, of course, does not imply transformation. While values activation can create the conditions for introspection and change, it can also facilitate the entrenchment of existing values frameworks.

In an early study of values activation, Rokeach (1968) used printed computer feedback to engage in values confrontation, a process by which individuals are confronted with comparisons between their own values framework and that of others. Inconsistencies between an individuals' values framework and that of others led people to alter their ranked preferences, showing that such feedback can activate values-based thinking and subsequently has a measurable influence over participant preferences. Hosack & Paradice, (2014) studied how values-focused feedback in a computerized decision support system could be used to understand and manage values-congruency conflicts. In this case, values feedback provided decisional guidance to the system user, thus influencing the decision-making itself and providing a way to assess the effectiveness of the support system in terms of achieving important values.

Activation of a value is linked to changes in decision-making behavior (Maio, Olson, Allen, & Bernard, 2001; Verplanken & Holland, 2002). As predicted by the principle of belief congruity (Rokeach, 1968) and applied by Hosack & Paradice, (2014), people are motivated to pursue behaviors that are consistent with their own values framework. Placing values under scrutiny can thus cause an individual to pursue consistency by further entrenching existing beliefs to protect their existing values framework, or by changing their incongruent behaviors, preferences, or values framework.

Given their foundational role in evaluation, leaving values unexamined represents a lost opportunity to improve the assessment and communication of important and complex decisions (Keeney, 1992). Values are drivers of the preferences and goals that guide decision-making (Sagiv et al., 2017). Correlations between choice preferences and values, and a crucial role for values in determining the importance of decision attributes, have been identified by Feather, (1995) and Verplanken & Holland, (2002) respectively. While people often do not always explicitly think about their own values while they are making everyday decisions, decision-making can be more purposeful and effective when they do (Keeney 1992; Verplanken and Holland 2002). This finding has important implications for participatory processes in group decision-making, as the quality of public input can be improved by prompting participants to consciously reflect on their values as an evaluative tool when identifying and comparing alternatives (Arvai, Gregory, and McDaniels 2001; Keeney 1992).

6-2.1 Previous Research Modeling Social Values for Decision-making Support

While scientific models traditionally treat values as static, and model builders as values neutral, approaches to decision-making that explicitly engage with social values are of growing interest to addressing environmental management and policy issues (Groenfeldt & Schmidt, 2013; Parnell et al., 2013). For example, Spatial Decision Support Systems (SDSS) have been a particularly active area of research to support decision-making regarding land-use and planning controversies. Cerreta & Mele, (2012) developed a Landscape Complex Values map by combining the Analytic Hierarchy Process and Geographic Information Systems in a Spatial Decision Support System. This map helped decision-makers to understand and integrate expert and community values into their decision-making framework. Brown, (2006) combined preference and values surveys with GIS software to better understand local preferences for tourism and development planning. Reed & Brown, (2003) used Values Suitability Analysis (VSA) to determine how well management activities aligned with public forest values. Focusing on conflict management, Brown & Raymond, (2014) and Brown, Kangas, Juutinen, & Tolvanen, (2017) used participatory mapping of preferences and values to assess the potential for conflicts to occur over development planning. Finally, public participation Geographic Information System (PP-GIS) surveys were used by Munro, Pearce, Brown, Kobryn, & Moore, (2017) to gain insights into local and non-local values for marine and coastal areas planning and management.

Moving away from spatial decision support to systematic decision analysis, Value-focused Thinking (VFT) (Keeney, 1992) constitutes a multi-attribute, multi-stakeholder approach to facilitated decision-making that explicitly focuses participants' attention on values and guides individuals and groups through a systematic process for identifying, articulating, and deeply evaluating their core values as part of a facilitated decision-making process. VFT has been applied to a wide range of decision contexts including the integration of public participation into environmental risk assessment (Gregory, Arvai, & McDaniels, 2001; McDaniels et al., 1999), water management and strategic planning (Morais, Alencar, Costa, & Keeney, 2013), tourism development (McDaniels & Trousdale, 1999), watershed management and planning (Merrick & Garcia, 2004), energy policy (Simon, Regnier, & Whitney, 2014) and climate change adaptation (Reid et al., 2014). Overall, participants who use VFT report being more satisfied with their participation and the eventual decision outcome. However, this process comes with mental and time burdens, as well as economic costs that are not readily available within municipal government contexts, thereby limiting the number of participants who can take part in facilitated VFT workshops (Bessette et al., 2016; Gregory, 2000a Gregory, 2000b; Keeney, 2004; Keeney, 1992).

The examination of value trade-offs has been operationalized into an online DSS for risk management and strategy development (Bessette et al., 2016) in order to reach a greater range of users, however Bessette et al. (2016) note that computerizing the values-based approach seemed to increase users cognitive stress. More recently, VFT has been combined with the Graph Model for Conflict Resolution (GMCR) in a Value-Focused Multiple Participant Multiple Criteria (MPMC) approach in order to integrate values into policy arenas (Williams & Fang, 2018). When using the VFT-MPMC approach, institutional values and citizen values are selected from explicitly stated sources such as strategic plans and documentation from political committee proceedings respectively (Williams & Fang, 2018).

The relationship between values and preferences over outcomes is, of course, often not direct or straightforward. Preference construction can be influenced by the information available, power structures during the evaluation process, external constraints and capacities, and cognitive shortcuts in the decision-making process (Gigerenzer & Gaissmaier, 2011; Hammond, Keeney, & Raiffa, 1998; Newell & Bröder, 2008; Newell & Shanks, 2014). While one method cannot resolve all of these complexities, the process of values-based decision support is designed to account for many of them, such that the final preference ranking is more coherent with the values of the participant than when values are left implicit.

6-3.1 Current Research

This research proposes and tests, for the first time, a values-based participatory tool that combines the theory of values activation with participatory modeling. Unlike VFT, P2P-DSS is designed to be delivered online and does not require users to follow a systematic value-focused program. Moreover, it is not necessary to pre-determine a user's deeply held values using tools such as the Schwartz Value Survey (Schwartz, 1992) or the Portrait Value

Questionnaire (Schwartz et al., 2001). Finally, because P2P-DSS is operationalized in an online format, it can capture input from participants who do not routinely attend public meetings, and have not thereby been included in previous public documentation captured by the VFT-MPMC technique.

P2P-DSS is unique in its use of interactive visual elements to achieve values-activation. Integrating social values into decision-making is an area of research with a wide range of applications and a great deal of momentum. However, to the authors' knowledge, there does not yet exist an approach that uses the interactive visual and design capabilities of an online interface to activate a focus on values in a non-systematic way that can be incorporated into online public opinion polls. Moreover, it does not require a user to engage in cognitive tasks that are any more taxing than ranking a set of alternatives from most to least preferred. Nonetheless, the act of making values trade-offs explicit adds a layer of deliberation to the task of providing public input. Thus, this system represents a new approach to connecting citizens and decision-makers through interactive modeling of the social values that drive decision-making.

6-3.2 Methodology: Design and Use of P2P-DSS

Objectives of P2P-DSS

P2P-DSS uses a values-centric approach to address issues of input quality, to facilitate the development of shared understandings between groups with different perspectives, and to generate new sets of data to support decision-making. P2P-DSS creates a shared interactive space where citizens and formal decision-makers can view and explore one another's perspectives in order to better understand one another's viewpoints on an issue. Formal decision-makers seeking public input can build a decision model with tools that make the values influencing decision-making explicit. This promotes self-reflection, values activation, and provides input for the participatory modules to be used by citizens. As public participants use the system to input their own ranked preferences over a set of proposed outcomes, visual and interactive cues facilitate explicit consideration of values trade-offs.

Integrating Values for Decision Support Using P2P-DSS

P2P-DSS centers the user's attention on specific pre-defined values that are conceptually related to the Theory of Universal Values (TUV) (Schwartz, 1992, 1994), which has been validated across cultures with over 10,000 individuals over decades of study (Hosack & Paradice, 2014). The TUV identifies ten universal values that seem to be present and measurable in all individuals (Table 6-1), with the hierarchical order of importance of each value to an individual representing a distinct values framework (Schwartz, 2012).

However, the definitions of the TUV values do not resonate with environmental issues, thus in order to increase ease of use of P2P-DSS the default values used throughout this study are adapted. The authors thus drew from the TUV (Schwartz, 1992) as well as literature related to Systems of Systems Engineering, Environmental Justice, Water Ethics, and consultation with a confidential participant who has a professional and formalized role in the decision context used in this study, to generate ten values-based statements for use in the program (Groenfeldt & Schmidt, 2013; Hipel, Fang, & Heng, 2010; Vanderwarker, 2012). The values integrated into P2P-DSS are summarized in Table 6-2.

Table 6-1 Key aspects of social values identified in the Theory of Universal Values (adapted from Schwartz 1992;2012).

Value identified in the Theory of Universal Values	Defining goals associated with each value
Self-Direction	Independent thought and action
Stimulation	Excitement, novelty and challenge in life
Hedonism	Pleasure or personal gratification for oneself
Achievement	Personal success achieved through demonstrated competence
Power	Social status, control over people and resources
Security	Safety, harmony and stability of society, relationships and self
Conformity	Restraint of actions that may upset, harm or violate social norms
Tradition	Respect, commitment, acceptance of customs and ideas provided by one's culture or religion
Benevolence	Preserving and supporting in-group well-being
Universalism	Understanding, appreciating, tolerance and protecting the welfare of all people and nature

Table 6-2 Values labels and descriptions used in P2P-DSS.

Value labels and statements used in the P2P-DSS model	
Value label	**Value description statement**
Justice	It is important to choose socially and legally just options
Fairness	It is important that all people receive fair benefits and burdens that result from this decision
Environmental Protection	It is important that the environment is protected by this decision
Security	It is important to protect safety and stability in society
Aesthetics	It is important to maintain and to create beautiful landscapes for citizens and visitors to enjoy
Enjoyment	It is important to provide people with opportunities for enjoyment
Social risk reduction	It is important to minimize the risk of negative social outcomes
Economic sustainability	It is important to make decisions that are economically viable for present and future generations
Development	It is important to promote development of local and national economies
Control	It is important to maintain personal / local control over services and social activities

Figure 6-1 shows the TUV values framework including 10 universal values organized around a segmented circle to illustrate their relative relationships along a motivational continuum (Schwartz, 2012). Values that are in close proximity (side by side) are complementary, meaning that satisfying one is likely to have a positive impact on satisfying the other. Values that are placed opposite one another are highly conflictual, meaning that satisfying one typically comes with a trade-off in relation to the other (Schwartz, 2012). For example, decisions that support achievement values typically conflict with those that pursue benevolence values, while complementing power values (Schwartz, 2012). Adjacent values are likely to be active at the same time, while opposite values are so dissimilar that they do not exert a strong influence in tandem.

Values placed in the same wedge (tradition and conformity) are associated with the same goals, and values closer to the center are more resistant to change. The TUV values are organized across the dimensions of ‘openness to change’ ‘self-transcendence’, ‘conservation’ and ‘self enhancement’. These categorizations further illustrate conflict between values groups. For instance, the thick lines dividing values into opposite wedges places values associated with self-transcendence and those with self enhancement into opposite quadrants, illustrating the conflict between goals associated with supporting values such as universalism and benevolence which are characterized by concern for the welfare of others and those focused on the pursuit of power and achievement which are associated with personal interests and dominance (Schwartz, 2012). The P2P-DSS values are included in Figure 6-1, distinguished by parentheses and italic font. The P2P-DSS values are located in proximity to the TUV values to which they are most closely related. Thus, 'Environmental Protection' and 'Reduce Social Risk' share motivational goals with TUV Self-Transcendence values of Universalism and Benevolence while Economic Sustainability and Security, share more motivational qualities with Conservation Values.

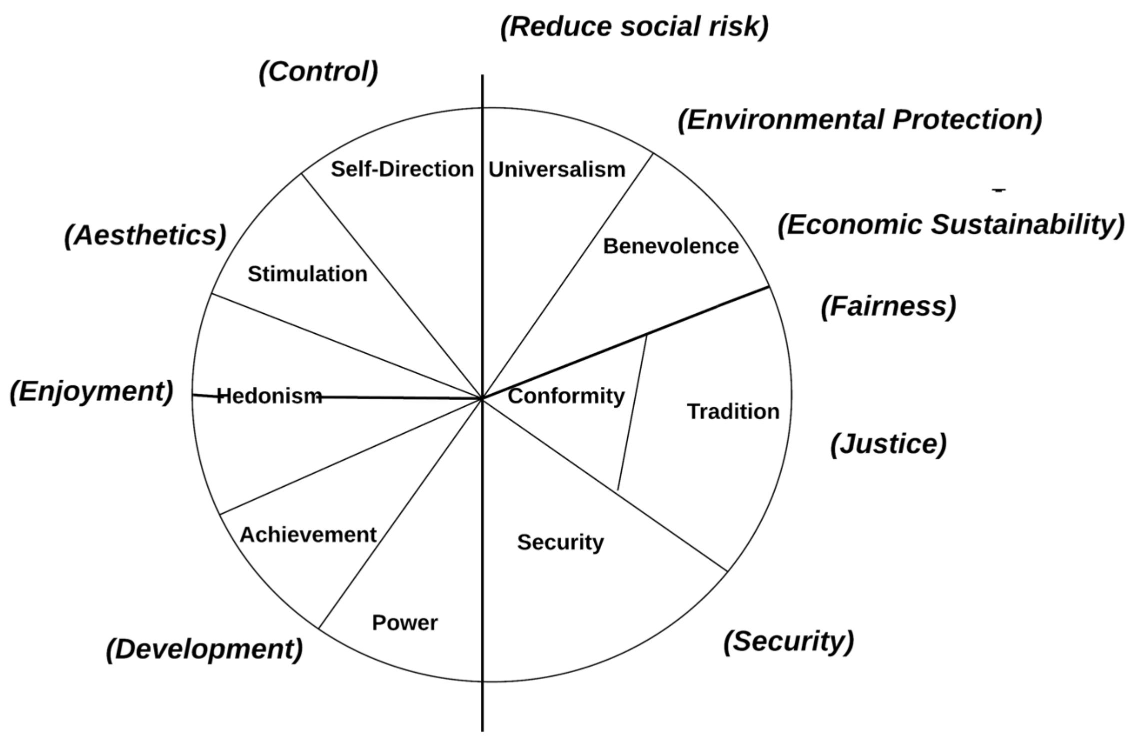


Figure 6-1 Universal values from the TUV and socio-environmental values integrated into P2P-DSS (shown in parentheses) (Adapted from Schwartz et al. (2012)).

Connecting Values Frameworks to Policy Proposals

The primary interactive elements in P2P-DSS are proposal cards (proposals) and options. Options are potential moves that the decision-maker may or may not choose to pursue, and proposals are feasible combinations of options that result in a particular outcome. The relationship between proposals and options can be summarized as:

(1)

If Option i is not selected for Proposal j then
$P_{ij} = 0$
If Option i is selected for Proposal j then
$P_{ij} = 1$

Thus, in P2P-DSS each proposal is a subset or equal to the total number of options available for selection. In the real world, this means that by choosing from the set of available options, and possibly by combining options, the decision-maker identifies a set of feasible decision outcomes, known as proposals, that are under consideration. Proposals are displayed in the P2P-DSS interface as cards that contain all available options with check marks to indicate which options have been selected for a particular proposal. Figure 6-2 shows a proposal that was calibrated for a real-world application described in detail in Section 6-3.3. In this example, all options are visible on the card, but check marks beside specific options indicate that in this proposal the outcome is to accept a proposed amendment with timeline and operational conditions. Full descriptions of the options shown in Figure 6-2 are provided in Section 6-3.3.

In practice, one can only select feasible combinations of options to create a meaningful or feasible proposal. For example, some options may be mutually exclusive. With respect to the example given in Figure 6-2 and explained in detail in section 6-3.3, one cannot choose the option Full Approval in combination with any of the other options.

During model development, a user assigns one or more values to each option, and then uses a ‘slider’ feature to indicate, from their own perspective, the relative influence a given value has upon the choice of a focal option (Figure 6-3). Moving the slider to the left or right decreases or increases the relative influence of that value over the option. For example, in Figure 6-3, a formal decision-maker has created an option to reject a mining application amendment based on concerns over impacts to groundwater. They have also indicated that choosing this option is based on values related to environmental protection and security. They have further signaled that environmental protection is the major driver of choosing this option, with security having a lower influence.

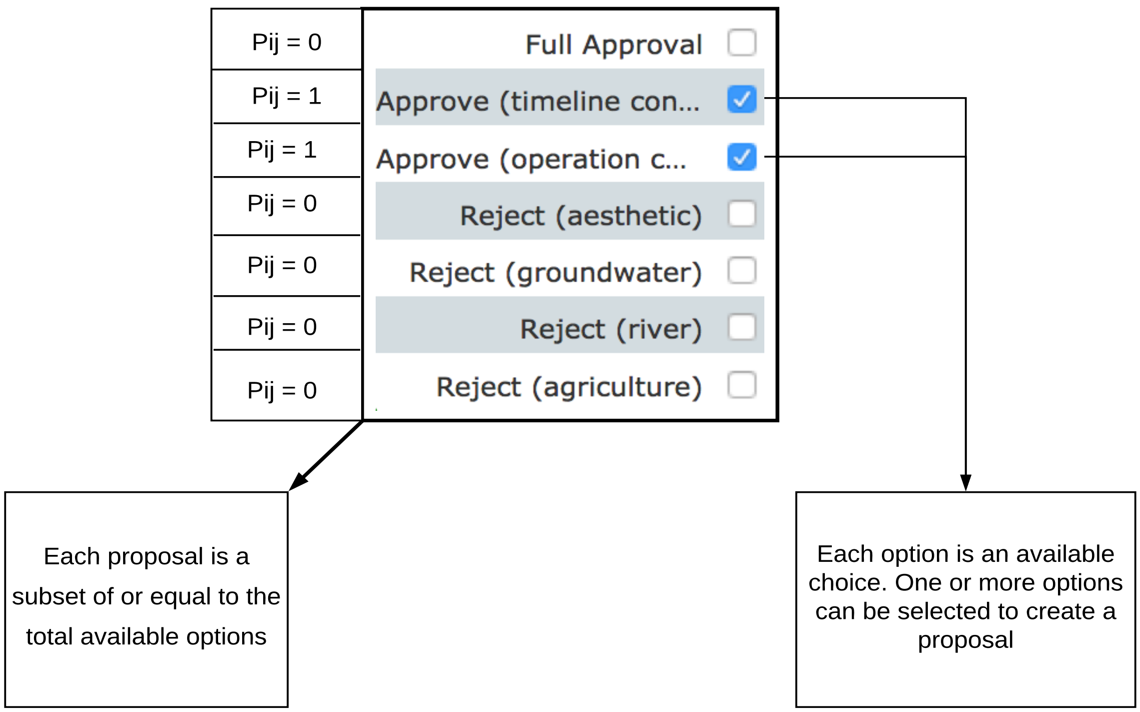


Figure 6-2 Individual proposal card used in P2P-DSS as generated in the course of this study of the Jigs Hollow aggregate application which is explained in detail in section 6-3.3.

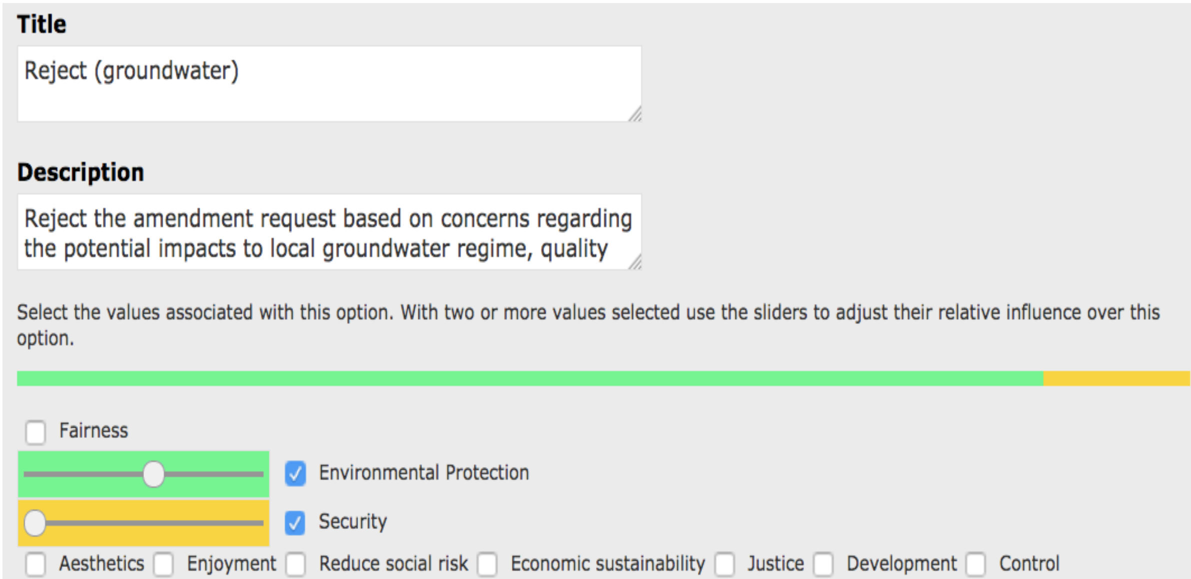


Figure 6-3 Slider features used to connect options with values weights. This feature provides the option title, a description of the option and a full set of values. The user chooses any values that are important to a focal option by clicking inside the box adjacent to it and uses the slider to determine the relative weight of that value over that option.

The algorithms governing the association of values with options contain a constraint such that the total values influence must be 100 percent, thereby embedding the concept of value trade-offs into the system because as more values are selected, their relative influence decreases. For each proposal, the software then determines how much of an influence a specific value is worth, and generates a relative number between 0 and 100 for each value. This number is then used to create a value profile for each proposal. An advantage of this approach is that values do not need to be specified manually for each proposal, as the number of proposals can rapidly exceed the number of options in cases in which the number of options is relatively large.

Options and proposals are used for several purposes. Firstly, they provide an organizational tool by which a formal decision-maker who wishes to seek public input can model the decision at hand and communicate the feasible outcomes that are under consideration. Secondly, by connecting options to values, the values assumptions of the model builder are made explicit during the modeling process. Thirdly, during the collection of public input, the proposals are used to collect preference rankings, by having the user move individual proposals along a continuum that ranks proposals from most preferred to least preferred. During this stage, ties are not permitted, which creates the need to evaluate trade-offs and mimics the situation of a formal decision-maker, facilitating the creation of shared understandings of the decision-making constraints.

Participants can also create new proposals if they believe that viable combinations of options have been neglected during the development of the model. Any new proposals created by the user can be placed alongside the other proposals at their preferred ranking spot. This provides participants with an opportunity to suggest their own alternatives that may have been overlooked by the formal decision-maker during the modeling phase. Being able to contribute in this way provides information back to the decision-maker as well as encourages greater engagement with the issue and participatory process (Bessette et al., 2016). Finally, the values-options connections provide the input needed to engage the interactive elements subsequently used by public participants.

Using P2P-DSS to Collect Public Input

Public participants can use P2P-DSS to learn about an issue, to provide input by ranking proposals from most to least preferred and to generate new proposals. For the first stage of the process the participant is provided with contextual information about the decision, links to relevant websites, and basic instructions on how to move the interactive proposals from left to right. This stage provides important information from the decision-maker to the public and calibrates an interactive feature known as 'the mirror' which is described in the next section.

The user ranks the proposals from most to least preferred and submits that ranking to move to the second stage of the system. The second stage in P2P-DSS provides information about social values, definitions of the values that are used in the model, and shows each participant their unique personal values framework using the mirror shown in Figure 6-4. Changing any modeling parameters, such as the option-values connections or the proposal ranking results in real-time changes to the mirror. When the user scrolls through the interface, the mirror remains in view, reinforcing a focus on values as they consider the issue. Participants are then asked to determine if they are satisfied with how the program displays their sense of values and their proposal ranking. If satisfied, they re-submit the same ranking as a confirmation.

If they feel that the mirror does not reflect their values, users can alter it by changing their proposal ranking, generating new proposals, or by altering the model assumptions using a 'protest' function. By clicking on a 'protest' button, the participant gains access to the same editing functions used by the domain expert to connect options and values. The participant can then delete the values included in the default model and input their own calibration. Through these steps, participants examine how their own preferences impact their social values and vice-versa before providing their preferred proposal ranking to the decision-maker.

The mirror feature depicts how much of an influence each social value had over the ranking choices made by the user by combining the inputted relative ranking with the unique values number generated for each proposal. If a participant ranks the proposals such that the proposals most influenced by a focal value are further to the left and then decrease to the right, then the ranking was influenced by that value the most; the opposite holds true if the ranking is reversed. This provides visual feedback related to how proposal preferences reflect the social values of the participant.

In order to generate the mirror, an algorithm calculates the worst and best scenarios for each value in which, 0 represents the worst and 100 represents best. The difference between the selected ranking and the worst possible ranking, and the best ranking and the worst possible ranking, is then calculated for a value to determine how much of the mirror a value occupies.

All interactions with the software are recorded in the P2P-DSS database. Submissions of preference rankings prior to values-activation are recorded and can be compared with the final submission. Moreover, all screen clicks are saved so that proposal movements can be analyzed even if they are not completed or maintained for submission. Proposals created by users are also saved, as well as all changes input by participants using the protest function.

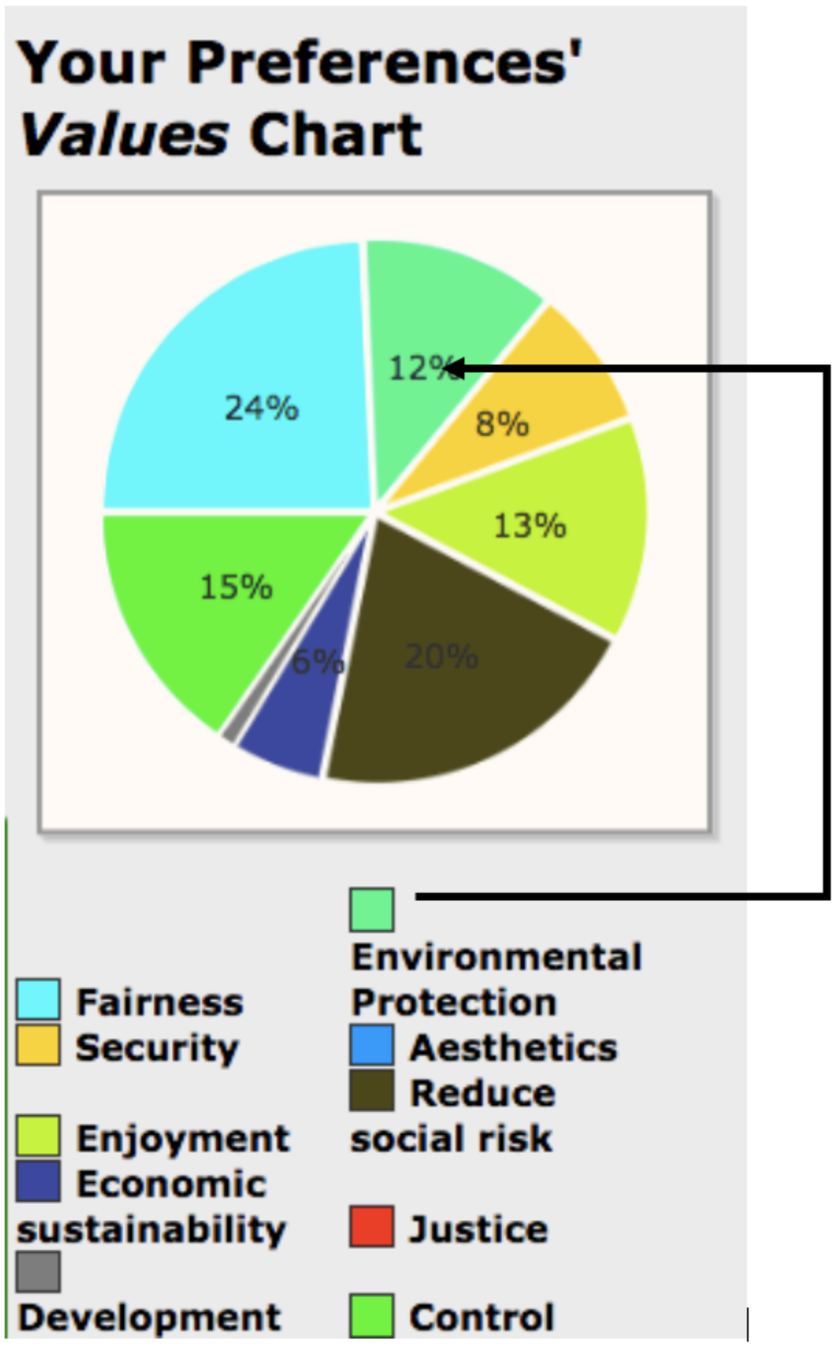


Figure 6-4 The Mirror: an interactive feature that displays a user's values framework throughout interactions with P2P-DSS. Color indicators beside the values labels indicate which wedge is associated with each value.

6-4 Illustrative Example: Using P2P-DSS to Collect Public Input for the Jigs Hollow Mining Amendment Application

The data generated through this research are illustrated using a real-world example about a mining permit amendment application in Ontario, Canada. The aggregate mining controversy was used in this study because issues of development, resources use, and conservation involve difficult values-trade-offs. Moreover, social values impact the priorities and mandates of citizens and environmental managers (McKinley, Briggs, & Bartuska, 2013), thus methods to better understand the role of values in these types of decisions can provide considerable insights to guide priority setting and environmental communications. This section describes salient aspects of the Jigs Hollow mining example in Ontario, Canada that is used to illustrate the functions and operations of the P2P-DSS program.

Context of the Jig Hollow Mining Permit Amendment

Land-use planning is difficult in part due to the interconnectedness of physical and ecological systems, diversity of potential issues, and the frequent need to consider the concerns of a variety of stakeholders with differing and often conflicting perspectives and goals in relation to specific decision contexts (Labiosa et al., 2013). These issues all came to bear in Ontario Canada, centered on an application to amend an existing aggregate mining permit.

In 2012, the Ontario Municipal Board (OMB) approved an agreement between the aggregate mining company, Preston Sand & Gravel Company (Preston), and the Township of Woolwich. This approval resulted in approximately 36 hectares of land being zoned and licensed for above water table extraction of aggregate materials. The specific permits zone the area as Extractive, but restrict activities with a holding provision limiting the company to above-water-table extraction (IBI Group, 2016).

In 2014 it became clear that the water table was higher than expected. To maintain the economic viability of the operation, Preston applied in 2016 to remove the holding provision (IBI Group, 2016). The proposed amendment generated opposition from local communities for a variety of reasons. For instance, equipment required for below water extraction will increase impacts on the landscape and may intensify noise levels and general disruption during operation. Moreover, while the original approval process required Preston to return the land to its previous agricultural use, the proposed plans preclude this option for a section of the permitted lands. Instead, the excavation pit will be transformed into a naturalized lake, resulting in permanent loss of prime agricultural land. Other consequences could include changes to local groundwater, with possible detrimental effects on nearby wells and cisterns used for both domestic needs and livestock; surface water changes, including impacts on a nearby fishery habitat; increased traffic and impacts to transportation networks; loss of cultural heritage landscapes and changes to the daily operations or the long-term time scale of the project (Desmond, 2016; Lafit, 2016)

Benefits associated with approving the project modification may include biodiversity and recreational opportunities provided by the resulting naturalized lake. The extraction of aggregate resources near growing local markets may be beneficial in terms of access to the materials for road construction and infrastructure projects (IBI Group, 2016). While mitigation strategies to address the potential negative impacts are required through the application process, citizen resistance to the modification indicates that the formal process may not have assuaged the concerns of the local community (Desmond, 2016; Lafit, 2016).

Model Development

This project focuses on the Jigs Hollow pit in 2017 when the amendment application was being considered. A model was developed in collaboration with a confidential volunteer with a professional interest in the Jigs Hollow mining activities, and a formal role in the decision about the amendment application. During two meetings, the volunteer developed a model using P2P-DSS. Throughout model development, the volunteer was able to ask any questions about the default social values and make changes to the values integrated into the study model.

The volunteer identified seven options that they considered to be possible in the decision (Table 6-3) and combined them into eight proposals (Figure 6-5). Of the eight proposals generated, seven were identical to the options available, meaning that only one option was selected. This is not a requirement of the program, but a characteristic of this particular study. One of the proposals was generated by combining two options, in order to approve of the amendment with timeline and operational conditions. The volunteer then used the P2P-DSS interface to connect specific values to options and to then add and reduce weights expressing the influence of each selected value over the choice of that option, using the toggle features. It is important to note at this stage that the goal is not to create a perfectly accurate or objective model, but to intuitively represent the perception of the model-builder. The content of this model was then used to collect input from a participant group.

Table 6-3 Options in the Jigs Hollow model. The name of the option is shown in the left column with a text description of that option in the right column.

Option	Option Description
Full Approval	Full approval of the amendment application
Conditional approval (timeline conditions)	Approve modification request with conditions on time period for operations
Conditional approval (operation conditions)	Approval modification request with conditions limiting hours of operation. This would constrain the noise impact on local residents, but may extend the duration of the project
Reject based on aesthetic impacts	Reject the modification application based on the increased anticipated landscape changes
Reject based on groundwater impacts	Reject the modification application founded on possible impacts on groundwater
Reject based on surface water impacts	Reject the modification application based on possible impacts to the nearby river and surface water features
Reject based on loss of agricultural land	Reject the modification application based on need to protect agricultural land from other competing uses

Study Group

After initial recruitment efforts using newspaper advertisements and social media outreach were unsuccessful, 15 individuals were recruited to use the P2P-DSS system using email lists and the snowball recruitment method (Neuman, 1997). Specifically, ten participants were university students recruited through email list-serves at the University of Waterloo, Canada, and five individuals identifying as non-students residing in or near the Township of Woolwich, Ontario, Canada were recruited using the snowball method (Neuman, 1997) that began with a member of the Woolwich community who had a previously existing interest in the Jigs Hollow mining application. All participants received a moderate compensation for their participation and travel costs.

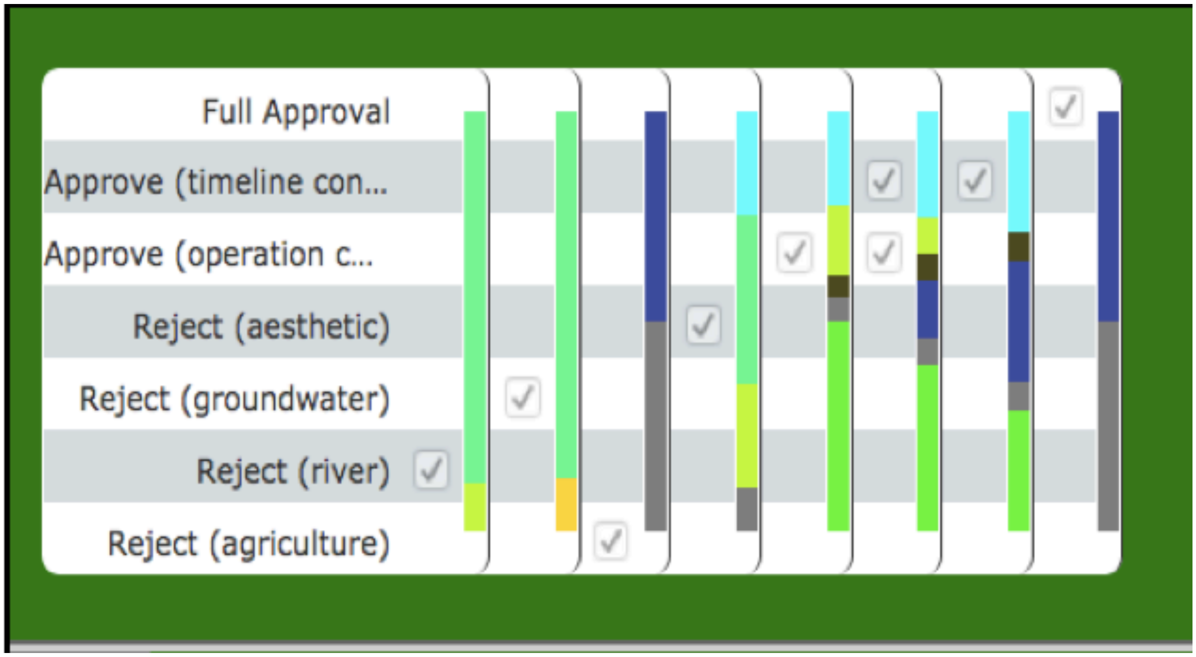


Figure 6-5 Proposals included in the Jigs Hollow model as shown in the P2P-DSS graphical user interface.

Participants used P2P-DSS to provide their input about the Jigs Hollow application in a controlled setting at a computer laboratory at the University of Waterloo in the Fall of 2017. Each participant was given basic instruction on how to move the interactive elements in the system before providing their input. To further explore the impacts and interactions using P2P-DSS from the user perspective, each participant completed a written survey immediately after submitting their input, answering questions related to their satisfaction with the system, their perceptions about the benefits and constraints of using P2P-DSS, and the impacts it had on their evaluation of the study. All volunteers were told that they could take as little or as much time as they wanted with the system.

6-5 Results

Data was collected from participant interactions with P2P-DSS and the follow-up surveys that were completed as part of this research. Because the authors' objective is to present the values-centric approach, and design elements embedded in P2P-DSS, an in-depth analysis of the preferences data is not the purpose of this paper. Instead, these results focus on written survey responses evaluating the impact of using the P2P-DSS from the participants' perspectives. Specific areas of concern that were addressed using surveys include assessing the legitimacy of the system as a means for participants to express their views in a way that is consistent with their own preferences and values; evaluating the capacity for this approach to activate values thinking and create the conditions to transform individual perspectives, and identifying novel insights P2P-DSS generates for reducing and managing conflict situations.

Evaluating the P2P-DSS Interactive Program

Questions were posed to determine if participants were able to use the system as a means to express their views, and to provide input that was consistent with the information they wished to convey. On a five-point Likert scale, ranging from dissatisfied to very satisfied, the majority of participants were satisfied that they were able to express their preferences related to the decision outcome while using P2P-DSS. Sixty percent of the participants were satisfied or better, while twenty-seven percent were neutral and thirteen percent were not satisfied. Moreover, eighty percent of the participants felt that using P2P-DSS helped them to state their own preferences, thirteen percent were neutral on this point, and seven percent found that it was unhelpful.

All participants completed all tasks in the program, although it was common for users to ask for assistance as they learned to move the proposal cards from left to right during the ranking procedure. This interactive feature proved to be the most difficult aspect of using the program, and while most participants became adept at this task within a few minutes, at times it did cause frustration. Ultimately, sixty percent of the participants were confident that they could use P2P-DSS without any assistance. From these results, it is clear that P2P-DSS holds promise to facilitate the collection of values-centric input but refinements to the user interface will be an important step to improve the user experience.

Evaluating the Impact of P2P-DSS over Preference

Questions were posed to evaluate if activating values as part of a public survey created the conditions to encourage users to re-evaluate and possibly adjust their preferences. Sixty percent of the participants responded that they felt that using P2P-DSS caused them to change their preferences a little. Based on the submissions collected using P2P-DSS, however, only thirty-three percent of the participants actually did change their rankings after seeing the values mirror and interacting with the software program. It appears that while the participants noticed a change in their evaluations, it was not always strong enough to influence their ranking in the decision context. Nonetheless, this evaluation is worth noting as it may indicate that the user has gained greater understanding of or sympathy for preferences that they do not hold, in spite of the strength of that understanding not changing their own preference ranking.

Twenty-seven percent of the participants felt that the system had no impact on their preferences, and the remaining thirteen percent indicated that they were even more strongly committed to their original ranking. This is consistent with previous findings about values activation in which individuals respond to evaluating their own values, or feeling that those values may be threatened through a variety of mechanisms including both strengthening or changing their values (Schwartz & Bilsky, 1987).

Indications of the impact of P2P-DSS on Deliberation

The authors explored the efficacy of this approach for encouraging users to carefully consider their public input in comparison to more traditional online methods of collecting opinions. Eighty-seven percent of the participants indicated that using P2P-DSS encouraged them to put more effort into considering their survey responses than they ordinarily would. The remaining thirteen percent of the participants stated that it neither encouraged nor discouraged greater consideration.

Evaluating P2P-DSS Insights for Conflict Management

Gaining insights into multiple stakeholder groups plays an important role in conflict mitigation and resolution. By allowing the public to evaluate and protest the connected values and options associations embedded in the expert model participants are able to see the issue from the perspective of a formal decision-maker. Seventy-three percent of the participants indicated that using P2P-DSS helped them to better understand the perspectives of people who do not share their preferences, while twenty-seven percent did not feel it had that impact. An in-depth analysis of the protests recorded using P2P-DSS is beyond the scope of this article, however, this analysis is provided in Philpot, Hipel, & Johnson (2019) which is included as Chapter 10 of this dissertation.

6-6 Concluding Remarks

This research proposed and tested a new approach to online values-based thinking that combines the theory of values activation with participatory modeling. By leveraging the visual and interactive capacity of online tools to activate values, this paper expands on previous research addressing how feedback can focus users' attention on their own values (Hosack, 2007). While this study reports on the responses of a small group of participants, it is hoped that this research will generate new opportunities for expanding the reach of values-based decision-making into *e*-participation.

Chapter 7

Context, Contributions, and Considerations Related to Aggregation of Participant Preferences in the P2P-DSS Jigs Hollow Study.

This chapter introduces the contributions that are made by the manuscript included in this thesis as Chapter 8. This chapter also provides comments and context related to the terminology used in the upcoming manuscript.

Individual survey responses are not particularly useful to decision-makers or researchers interested in the preferences of large groups of people. Information collected at the individual level needs to be processed to inform group decision-making. Thus, in order to explore the research question "How can one operationalize values-based decision-making for enhancing environmental management?", the manuscript included as Chapter 8 of this thesis addresses research objective 2: 'Identify and illustrate techniques and protocols to generate a collective preference ranking from individual preference rankings collected using the values-based approach'. In so doing, the primary contribution of this chapter is to expand the applicability of the approach such that it can be useful for informing environmental management and decision-making. This contribution creates an important foundation for future studies using P2P-DSS in which the collected data will be prepared for use by formal decision-makers concerned with issues of public interest.

The manuscript included as Chapter 8 contributes to this dissertation by demonstrating that in using a Modified Borda Count (de Borda, 1781; Emerson, 2013), the individual surveys described in the previous chapter are readily translated into collective preferences ranking that may be useful for providing information for decision-making, issue-framing, and conflict resolution purposes. The research summarized in this chapter proposes that a Modified Borda Count (de Borda, 1781; Emerson, 2013) is useful for creating collective preferences from individual inputs generated in P2P-DSS, and that the proposed values-centric online contributions may then contribute to the development of solution strategies for formal decision-makers who wish to align their decision-outcomes with the values and preferences of groups of people.

The reader should bear in mind that the size of the participant group used in this study is too small to represent community preferences and the purpose here is restricted to demonstrating the methodology. References to 'local', 'nearby' or 'more distant' participants refer only to their stated location of residence and is not intended to imply that their preferences represent those of the community at large. As an illustration of the protocol the participant group was divided into sub-groups based on location and all subsequent discussion is intended only to refer to the participant group.

It is worth noting that the term case study is used in the manuscript included as Chapter 8 which was submitted for publication in 2017, while it has not been used in the manuscript included as Chapter 6 of this thesis which was submitted in 2019. This change was made to add clarity and consistency for readers from different disciplines and to avoid any confusion that could occur from application of the term 'case study'.

The rationale for referring to this work as a case study in 2017 was based on specific characteristics of the research, however, as there is room for disagreement about what constitutes a case study, (Robson, 1993; Runeson & Höst, 2009), this choice initiated some reflection that warrants discussion. This work shares many features common in case studies (Neuman, 1997). Namely, it involves the use of multiple methods of data collection to gather information from many sources during a specific event (Neuman, 1997; Robson, 1993; Wohlin & Aurum, 2015; Yin, 2013). For example, a formal decision-maker provided input during an interview and by building a model. Fifteen volunteers then provided data through recorded interactions with P2P-DSS, by submitting preferences rankings, and by completing a post-task survey. This work was focused on the specific act of providing input about the Jigs Hollow mining application using P2P-DSS, and that event is examined in detail at a specific moment in time.

In other respects, this project may not meet the criteria of a case study as defined in many fields in the social sciences. For example, case studies in psychology typically refer to a deep analysis of an individual or a community during a specific event, or analysis of several such cases connected by a common theme (Robson, 1993). However, it is not uncommon in the Decision Sciences to apply the term 'case study' to research involving limited participant sizes and in which participants attend laboratories to use a prototype computer system under development rather than being in a natural setting. This is particularly true when the research focus is decision support development or the illustration of decision support processes (see, for example Bessette et al., 2017; Henriques & Louis, 2011; Hipel, Kilgour, Fang, & Peng, 1999). Acknowledging that these qualities may complicate the use of the term case study for scholars in other fields of the social sciences, and to better reach an interdisciplinary audience, the authors thus chose to omit the terminology of case study following the publication of this article. Minor formatting and editorial changes have been made to improve clarity and consistency with the dissertation.

Chapter 8

Analysis of a Below-water Aggregate Mining Case Study in Ontario, Canada Using Values-centric Online Citizen Participation

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Philpot S.L.[a] Johnson P.A.[a], Hipel K.W.[bcd],
[a] Department of Geography and Environmental Management, University of Waterloo, Canada.
[b]Department of Systems Design Engineering, University of Waterloo, Canada.
[c] Centre for International Governance Innovation, Waterloo, Canada.
[d] Balsillie School of International Affairs, Waterloo, Canada.

Abstract:

Citizen perspectives on a controversial aggregate mining application amendment are elicited using an online participatory platform P2P-Surveys. The interface uses interactive visual cues to focus the subject's attention on their social values framework as a decision-aide. Interactive elements encourage learning by providing values feedback and then allowing the subject to adjust their preference input or to change the values-modeling parameters prior to submitting their responses. Individual preference rankings are then aggregated using a Modified Borda Count for subsets of the participants. The resulting group preference rankings provide insights useful to researchers interested in the interface between social values and environmental decision making, and for decision makers who wish to harness citizen input for integrated decision making. A real-life case study for citizen input into a below-water aggregate mining controversy in Southern Ontario, Canada, is utilized to explain this new methodology and to demonstrate the useful information generated to assist in resources management decision making.

Keywords: values; decision making; participatory modeling; planning; aggregate mining

8-1. Motivation

Diminishing availability of aggregates (sand, gravels, clays, stone, earth, bedrock) for infrastructures can limit the development and maintenance of built spaces (Peduzzi, 2014). Globally, growing populations, ageing infrastructure, and rapid urbanization conspire to threaten the sustainability of non-renewable aggregate resources, leading towards negative social and environmental outcomes (Torres, Brandt, Lear, & Liu, 2017). Aggregate scarcity means that mining activities are increasingly taking place in sensitive ecological areas and in closer proximity to human settlements, resulting in conflict over competing values regarding desirable uses for land and its resources. If aggregate management strategies are to be equitable, robust, and sustainable, decision-makers must be able to effectively consider complex value trade-offs, non-commensurable factors, and the values of impacted communities. Moreover, these conflicts can be particularly vexing because the social need for the resource and the highly localized negative impacts distribute the benefits and burdens of development disproportionately across space (Esteves, 2008). Thus, resolution of these disputes requires an understanding of the interplay between local experiences and global perspectives in order to respond to the values and requirements of impacted communities and broader society alike. In spite of aggregates' importance and the changes that extraction activities impose on socially valued landscapes, their management is understudied with very little long-term information available on amounts extracted and the impacts of this sector on nearby communities (Krausmann et al., 2009; Peduzzi, 2014). Developing and evaluating ways for citizens to contribute to aggregate management research and decision-making will play an important role in the development of effective governance systems, with corresponding implications for resource management, sustainability, development and justice.

On-line participatory platforms connecting citizens to government decision-making, often framed as electronic democracy (e-democracy), are already opening up opportunities for citizens to engage with formal decision-makers and generate new types of data and data sharing relationships (Johnson et al., 2015; Lourenço & Costa, 2007). While early online opinion collecting tools were limited to administering a service equivalent to paper surveys over the internet, new tools have the flexibility to add innovative services meeting a growing variety of decision supporting needs (Evans & Mathur, 2005). Online tools can be used to create new sets of knowledge, when design elements are harnessed to increase creativity in the formulation, collection, and integration of input (Johnson et al. 2015). In this article, the authors present insights gained when residents in and around the Township of Woolwich, Ontario, Canada, used a novel participatory modeling tool to rank their preferences about a contentious aggregate mining application. This tool, 'Public to Public Decision Support System' (P2P-DSS) (Philpot et al. 2019a;2019c) uses visual and interactive cues to focus users' attention on how their preferences affect the achievement of broad social values, from both their own perspective and that of formal decision-makers (Philpot et al. 2019a). Preferences submitted by volunteers using P2P-DSS are then aggregated using a Modified Borda Count (MBC) (de Borda, 1781; Emerson, 2013). In this real-life study, response patterns based on spatial distance from the impacts of the mining activity are analyzed. The results are then used to generate insights that are useful for formal decision-makers who wish to inform their own decision-making with an understanding of citizen values and preferences. Specific findings indicate a strong collective preference to reject an application to permit below water-table aggregate extraction at case study site, the Jigs Hollow aggregate mining pit. Opposition to the application is primarily driven by concern over negative impacts to nearby water sources. However, other motivations behind rejection are differentiated based on location, with community members valuing the aesthetic rural landscapes under threat, and this priority decreasing strongly with distance from the local community. Overall, this work illustrates the types of information that can be obtained by combining values-based evaluations with the MBC aggregation method using P2P-DSS.

8-2. Case Study Context

In section 8-2 the authors provide important context related to the Jigs Hollow mining application. Section 8-2.1 provides legislative context related to aggregate mining in Ontario, Canada, while Section 8-2.2 describes the state of the Jigs Hollow aggregate amendment application at the time of analysis.

8-2.1 Aggregate Governance in Ontario

The mining and management of aggregates in the Canadian province of Ontario is governed in part by the Ministry of Natural Resources and Forestry (MNRF) who ensure that aggregate mining is conducted in compliance with the Aggregate Resources Act (ARA 1990-C.A.8) and by any other legislation that may become relevant with the specifics of activities and location, such as the Planning Act *(1990-C. P.13*)the Ontario Water Resources Act *(1990-C. O.40*) the Environmental Protection Act *(1990-C. E.19*) and the Endangered Species Act *(2007-C. 6*). MNRF fulfills its mandate by monitoring aggregate mining activities, enforcing compliance, ensuring that sites are rehabilitated as required and responding to any complaints. While legislative power rests primarily with the Province, some regional and local influence is shared through activation of the Planning Act. Fees for extraction are similarly distributed across spatial and political boundaries, with 3% of all fees reserved for Aggregate Research, 61% distributed to the local municipality, 15% to the regional municipality and at least 21% reserved for the Crown ("Government of Ontario," 2014).

Beyond official governance entities, social license to operate is an increasingly important concept for aggregate mining operators wishing to minimize conflict with local communities. Social license refers to the level of community acceptance of a company's extraction activities (Esteves, 2008). Achieving this acceptance is particularly challenging given increased community awareness of the potential for negative outcomes from aggregate extraction, and the spatial disparities between the ecological and social footprints of mining and the benefits in terms of fees distribution and infrastructure development. Monitoring and managing the social consequences of aggregate mining can provide insights into ways to strategically distribute benefits to gain this social license (Esteves, 2008). However, identifying opportunities to align thresholds for business viability with community interests requires a comprehensive understanding of how social values motivate citizen preferences

8-2.2 Study Area

In 2012, the Preston Sand and Gravel Company (Preston) received approval for above-water-table extraction of aggregate materials from 36 hectares of land, known as Jigs Hollow, in the Township of Woolwich, Ontario, Canada (Figure 8-1). The permit restricted Preston to above-water-table extraction only and required the company to restore the site to agricultural land following completion of the aggregate mining. However, when work began in 2016 the water table was found to be elevated above expectations and Preston requested an amendment to the extraction agreement so that it could extract below the water table (IBI Group, 2016; Philpot et al. 2019a, 2019c). Below water table extraction requires a more invasive set of equipment, altered timetables, and makes it impossible to restore the landscape to its original status as agricultural land. Instead, Preston proposes to alter their restoration goals to creating a naturalized lake once mining has ceased (IBI 2016). Those living near the site have voiced opposition to the amendment (Desmond, 2016). Because below-water-table extraction creates meaningful changes that impact well-being, resistance to the amendment may emerge from many different concerns. In order to better understand how this change is perceived by the public, the authors initiated a values-centric approach to eliciting online citizen input in 2017, while the amendment was under consideration.

8-3 Previous Work in Value System Elicitation

In Section 8-3, the authors summarize relevant research on preference and values modeling for integrated decision-making, the underlying theories and methods for operationalizing values in formal decision-making frameworks, and recent research directed towards harnessing values as a tool for online participatory decision-making.

8-3.1 Modeling Preferences and Values for Integrated Decision-making

Various techniques are used to elicit human preferences and priorities for policy-aiding and decision-making. The Analytical Hierarchy Process (AHP), for instance, can be used to facilitate the prioritization of options using cardinal pairwise comparisons (Saaty, 2008). However, expressing ordinal, or ranked preferences better reflects how people think about their own preferences in real-world decision-making (Moshkovich, Mechitov, & Olson, 2002). In conflict analysis, the Graph Model for Conflict Resolution (GMCR) (Xu et al. 2018; Fraser and Hipel 1984; Kilgour et al. 1987; Hipel et al. 1993; Fang et al. 2003) employs Option Prioritization, to intuitively rank outcomes based on relative importance over feasible options (Fang et al. 2003a; 2003b). Regardless of the method of elicitation, once collected, preferences form an important source of information for subsequent analysis. In many cases, preferences provide sufficient data to integrate stakeholder values, as they emerge from the value systems of a decision-maker (Xu et al. 2018), yet, they are distinct phenomena.

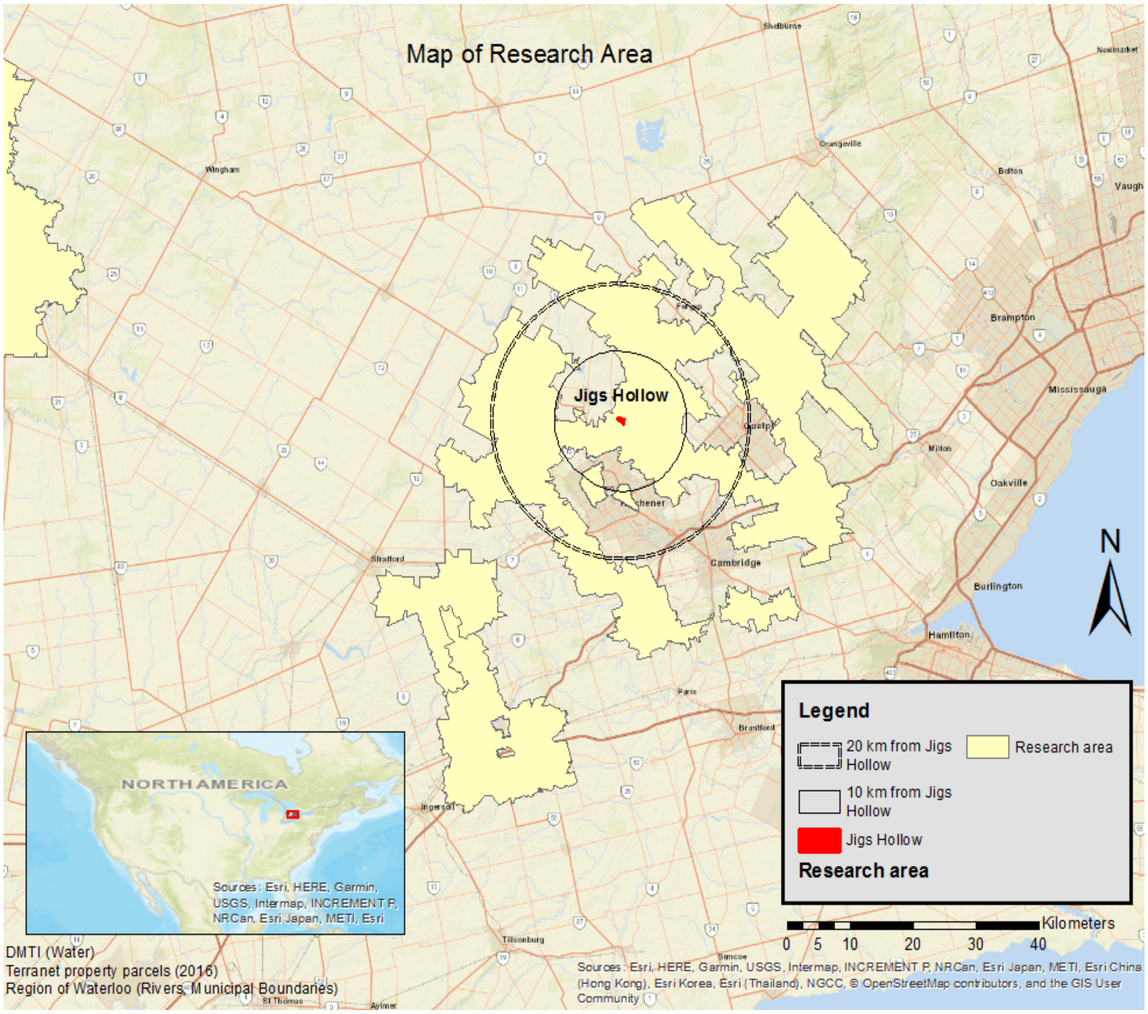

Figure 8-1 Map of research area showing the Jigs Hollow mining site in Ontario, Canada. Shaded areas indicate areas in which participant volunteers resided. Concentric circles surrounding the Jigs Hollow site demarcate distance from the mining activities, at 10km, and 20km respectively.

Values are foundational motivators that are more stable and trans-situational than preferences (Schwartz, 2012; Schwartz & Bilsky, 1987). While articulating preferences over a decision reflects the value-system of the decision-maker, the underlying values remain implicit and unexamined. Advancements in social psychology and decision analysis indicate that framing decision-making around values provides unique opportunities for social learning, developing shared understandings of complex problems, and conflict resolution (Arvai et al., 2001; Grube et al., 1994; Keeney, 1992; Rokeach, 1968). Moreover, conscious consideration of values during decision-making can have a transformative or re-enforcing impact over preferences that is not typical when values remain unexamined (Keeney 1992; Schwartz and Bilsky 1987). Thus, making social values explicit as part of a participatory process provides unique insights into the motivating factors that drive the evaluation of potential decision outcomes as well as facilitating transformational and educational goals associated with public participation initiatives.

8-3.2 Aggregating Individual Preferences for Group Decision-making

Aggregating individual preferences into a group social function is an important step towards creating useful and practical advice for policy and decision-making. The aim of aggregating is to capture individual judgments and process them such that they convey a shared social reality that can be used to inform or justify decision outcomes. Developing a collective preference from a set of individual preferences can be achieved through one of a variety of voting method protocols, each with unique characteristics (Morais & De Almeida, 2012). The choice of aggregation protocols involves evaluating the limitations and advantages of specific approaches, each of which involves important trade-offs (Burgman et al., 2014).

In Simple Majority voting, each voter can only cast one vote for a single alternative. The votes are then summed for each alternative, with the highest count considered the winner. In this winner-take-all approach, voters (or stakeholders) are limited in their capacity to provide meaningful information and to influence the decision outcome because their input does not provide preference data for the full preference set (Burgman et al., 2014). Moreover, in situations with a non-trivial number of alternatives, the winner may have received only a small proportion of the votes resulting in an unsatisfactory outcome even from the perspective of the majority of voters. Approval voting, in which individuals vote for all of the acceptable alternatives from their own perspective, and the alternative with the largest total number of votes is the winner results in the selection of moderate alternatives that satisfy the groups on average, but are not ideal choices from any individual perspective (Burgman et al., 2014; Kangas, Kangas, 2002).

Ranked preferences approaches, on the other hand, such as Condorcet Functions and the Borda Count, capture the preference information of the individual for their entire set of alternatives, thereby providing a greater wealth of information to decision-makers, and greater participation for the individual contributing their data (Burgman et al. 2014). The

Condorcet Function is a simple majority method that identifies an alternative which the majority of decision-makers prefer (Burgman et al., 2014; Morais & De Almeida, 2012), but can result in intransitive outcomes which are counter-intuitive from the perspective of participants.

The Borda Count distributes the number of votes to the alternatives based on their relative position on each individual ranking, and then sums the votes applied to each alternative to generate a group preference model (de Borda 1781, such that in a situation with n alternatives, the most preferred alternative receives n points, the second most preferred receives n - 1, and so on until the least preferred option receives 1 point. This protocol has been used previously in environmental decision-making for forest management (Burgman et al., 2014; Hiltunen, Kurttila, Leskinen, Pasanen, & Pykäläinen, 2009; Kijazi & Kant, 2010). One important disadvantage of this approach, however, is the interdependency of the ranked alternatives. This means that removing or adding alternatives to the ranked set can have meaningful impacts on the ranking of individual alternatives to one another (Emerson 2013).

Although Borda himself did not address this drawback, subsequent researchers have developed a variety of modifications to handle incomplete rankings in which one or more participants vote for only a subset of the potential alternatives (Emerson, 2013). Untreated Borda Count and Averaged Borda Count modifications allocate '0' votes to alternatives that are not ranked by a participant, and average out the remaining points to ranked alternatives. One drawback to these approaches is that they dis-incentivize full participation by offering an advantage to the participant's most-preferred option if they throw away least preferred options. An MBC, on the other hand, promotes full participation by always allocating one more vote to alternative i than alternative j if alternative i is ranked as more preferred to j by one placement on the ranking (Emerson, 2013). This can be expressed in the following rule: With a ranking of n alternatives, in which each alternative is ranked from most to least preferred, the votes are allocated as (n, n-1, n-2, n-3…..1). In this way, when individual rankings are aggregated, the most preferred option of a participant p will only receive a 1 point advantage over the other options if p only ranked two alternatives, whereas if the full set of alternatives is ranked then the most preferred option receives a 1 point advantage over the second most preferred option, a 2 point advantage over the third choice, and so on, resulting in a significant advantage of the lesser preferred options when many alternatives are being considered (Emerson 2013). With this modification, the Borda count is an excellent aggregate option that accounts for the voters' preferences across the full set of alternatives, while offering the flexibility to include ranking submitted with only partial voting (Emerson 2013).

8-3.3 Operationalizing Values for Participatory Decision-making Using P2P-DSS

Aspects of a newly developed values-centric decision support system, P2P-DSS, were originally presented at the 2017 Group Decision and Negotiation conference held in Germany (Philpot et al. 2017). A study was pursued based on the Jigs Hollow aggregate mining site. Using P2P-DSS, a domain expert created a model of the decision context, including background information, possible decision outcomes (proposals) based on combinations of feasible options, and input about how the expert perceived decision options would influence an important social value, all integrated into the model using the interactive P2P-DSS interface. Graduate students from the University of Waterloo were then invited to interact with the model in order to gain insights into the case study and to submit their preferences by ranking the proposals from most to least preferred. The students were then asked to complete a written survey to evaluate the experimental approach in terms of ease of use, legitimacy of their submitted rankings, the impact that the values-centric elements of P2P-DSS had on their preferences, and the potential for their rankings to influence decision-making. The pilot study provided guidance for improving the user interface and the experimental approach.

The second stage of the research included public participants from in and near the Region of Waterloo and the University of Waterloo community (Philpot et al. 2019a). Fifteen participants used P2P-DSS to learn about the Preston application amendment described in Section 8-2 and to input their preferences. The participants also completed a written survey to contextualize their responses and assess their experience using this participatory approach. Philpot et al. (2019a) described the program design, and summarized key findings from the use of this participatory approach. Overall the program showed promise as a tool for values-centric participatory decision-making, with the majority of participants indicating that P2P-DSS helped them to state their preferences, encouraged them to spend more time in consideration of the issue, and helped them to understand the perspectives of the modeler, when their perceptions differed (Philpot et al. 2019a). In this article, the authors expand upon previous work by providing an in-depth analysis of the preference data collected using P2P-DSS and illustrating the novel insights that can be gained from aggregating the ranked preferences inputted using P2P-DSS. This represents an important expansion of the preliminary work by demonstrating how to develop a social value ranking from P2P-DSS data such that useful policy recommendations can be generated for decision-makers who wish to gain a better understanding of citizen values and preferences.

8-4. Methodology

Making decisions that reflect the objectives of a group requires aggregation of individual preferences to create a group utility framework. Section 8-4 describes the process of collecting individual preference rankings using P2P-DSS, and the analysis used to generate a collective preference from the individual rankings. Section 8-4.1 describes the process of inputting individual preferences, while the analysis is summarized in Section 8-4.2.

8-4.1 Data Collection

Citizen preferences were collected when participants used P2P-DSS to learn about and provide their input regarding the Jigs Hollow amendment application (Philpot et al. 2019a; 2019b). After a brief description on how to use the P2P-DSS interactive interface, each participant accessed the appropriate survey from the P2P-DSS homepage. The first page provides a brief overview of the focal issue, optional links to websites with further information, and a graphical representation of viable decision outcomes represented as proposals displayed in a randomly ranked order. A proposal is shown in Figure 8-2, note that all options are included, but the option 'Accept (timeline conditions)' has a check mark. This indicates that the proposal represents the choice to accept the below groundwater application, conditional upon requiring timeline restrictions not already included in the amendment. Figure 8-3 shows the full set of proposals for this case study. By including options to accept and reject the application for various reasons, the authors are able to gain insights into the concerns and perceptions that are driving participant's decision-making about the amendment.

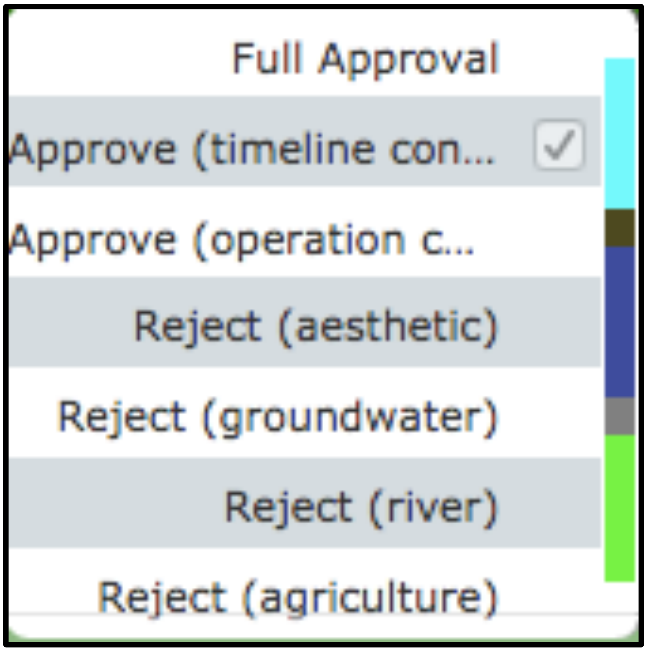

Figure 8-2 A proposal as shown in the P2P-DSS interface. Note that each proposal is depicted on a card that includes all options; However, the check marks indicate which options are active on the focal proposal. For instance, this figure proposes to accept the mining amendment application if and only if timeline conditions are added to the agreement.

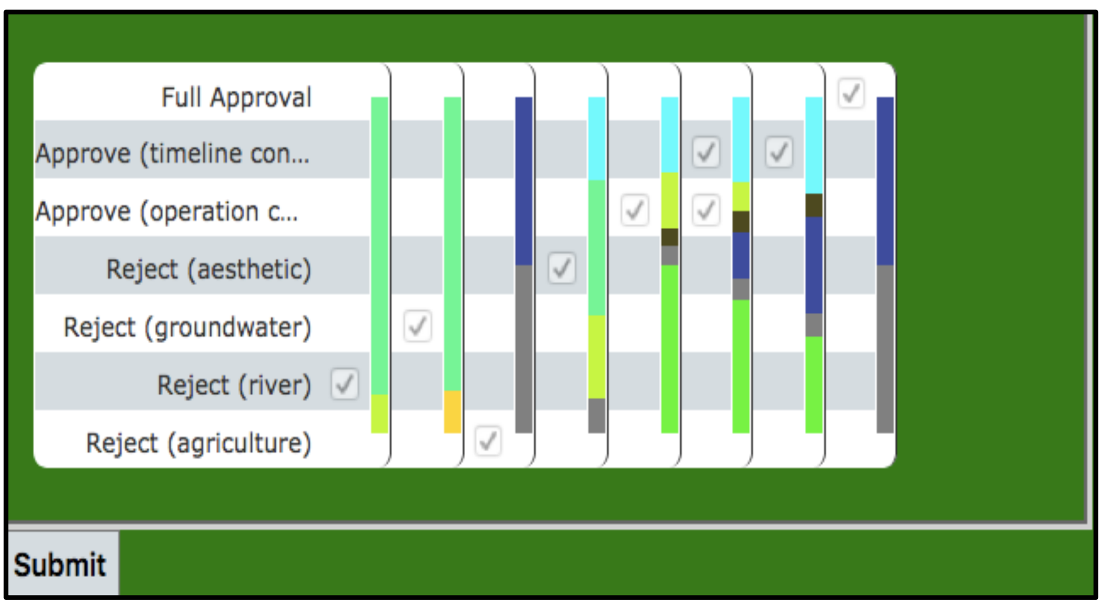

Figure 8-3 The full set of proposals under consideration in the expert model as displayed on the P2P-DSS interface.

Descriptions for each option are available by scrolling down the screen and are shown in Table 8-1. Participants then rank proposals by moving individual proposals from left to right. Every movement to the left indicates that the proposal is more preferred than the proposal located to its right. For example, Figure 3 displays a preference ranking for a participant whose most preferred choice was that the amendment should be rejected based on possible negative impacts to the nearby river (Reject-River). Their second most preferred option was rejection in order to protect local groundwater from potential negative effects, and so on, until their last preferred option of full acceptance of the amendment. Once the participant is satisfied with their ranking, they submit it to the DSS database by clicking on the submit button. The DSS then directs the participant to the second page.

Table 8-1 Descriptions of the available options modeled in the P2P-DSS Jigs Hollow case study (Philpot et al. 2019a).

Option	Option Description
Full Approval	Full approval of the amendment application
Conditional approval (timeline conditions)	Approve modification request with conditions on time period for operations
Conditional approval (operation conditions)	Approval modification request with conditions limiting hours of operation. This would limit the noise impact on local residents, but may extend the duration of the project
Reject based on aesthetic impacts	Reject the modification application based on the increased anticipated landscape changes
Reject based on groundwater impacts	Reject the modification application based on possible impacts on groundwater
Reject based on surface water impacts	Reject the modification application based on possible impacts to the nearby river and surface water features
Reject based on loss of agricultural land	Reject the modification application based on need to protect agricultural land from other competing uses

Data collection continues on page two of P2P-DSS with a value-centric module. Pre-determined social values that may be driving participant's decision-making while ranking the options are made explicit using descriptive text, a visual element known as the 'mirror' (Figure 8-4) that depicts a personalized values framework for each participant, and color coding embedded on the ranked proposals that illustrates which values are modeled as important to the proposal. The user can then alter the values mirror to better match their own perceived values framework by changing the proposal ranking, creating new proposals and adding them to the ranked set of proposals, or by clicking on ‘protest’ - an option that allows users to change the underlying model parameters that determine how each option influences the social values included on the mirror (Philpot et al. 2019a; 2019b). Once satisfied with their proposal ranking and values framework, participants complete the survey by clicking on a submit button. The first submission is used to calibrate the values framework and for research purposes for which it is useful to compare user interactions between the options-oriented ranking on the first page and the subsequent values-centric activity on the second page. The second page submission constitutes citizen input that is an aide to decision-making.

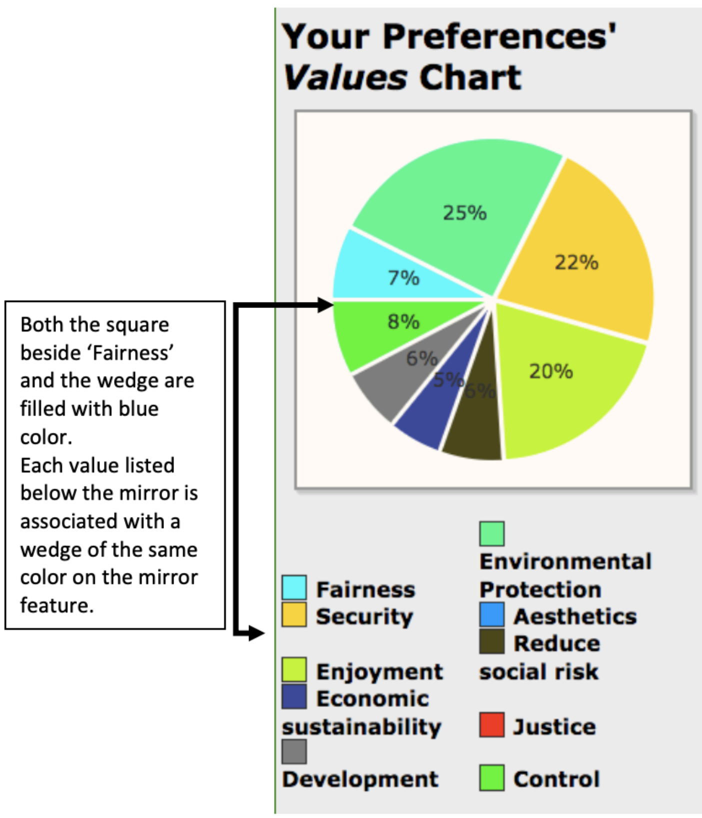

Figure 8-4 The mirror feature which serves to activate values-centric thinking by providing values feedback to the participant after their initial proposal ranking. This interactive feature depicts a personalized values framework generated for each participant based on the expert model calibration and the individual participants’ proposal ranking. Interactions such as re-ranking the proposals, generating new proposals, and changing the underlying model calibration all result in real-time changes to the values framework.

This experimental process was followed by 15 participants at computer laboratories at the University of Waterloo. Participants received instructions on how to use the interactive interface, and were free to ask questions. In all other respects, participants were asked to complete the program as if they were filling out an on-line survey in a comfortable place such as their own homes. While future studies will be conducted completely on-line, the exploratory phase of this research benefited from interaction with the participants. In particular, it was noted that the movement of proposals in order to rank them was a challenge for some users. Thus, instructional videos and improved design elements will be integrated in the next research phase.

8-4.2 Analysis

In this work, the authors apply a MBC method such that the rankings are scored: (first, second, ….last) : (n, n-1, ….1) in which n is the number of proposals ranked (Emerson 2013). New proposals created by participants were not included within the collective ranking. However, they are recorded such that they can be submitted to decision-makers for consideration. Analysis was then conducted for subsets of the participant group including local participants residing within 10 km of the mining site (Local), who are most likely to be impacted by potential localized negative outcomes such as groundwater changes, noise inconveniences, and disruptions to transportation networks, and are likely to have received community information about the mining site. The second sub-group analyzed included participants living within 20 km of the mining site (Nearby). These individuals may feel a connection to the Woolwich community, and may be concerned about transportation disruptions and negative impacts to the nearby Grand River which passes by Jigs Hollow, before meandering south-east to Lake Erie, by way of Kitchener-Waterloo (Figure 8-1). The authors then examined the responses of participants who resided more than 20 km away from Jigs Hollow (Farthest) and are less likely to be impacted to the local effects of the mining activities. Finally, a globalized analysis was conducted including all participants.

8-5 Results and Insights

Section 8-5 presents the analysis and interpretation of preference rankings collected using P2P-DSS. Results include collective preference rankings generated at multiple distances from the mining operation. Overall, a consistent trend is the collective preference to reject the application amendment to permit below water-table extraction based on concern over potential negative impacts to groundwater. Section 8-5.1 summarizes the study results while interpretation and discussion of the findings is provided in section 8-5.2.

8-5.1 Findings

Table 8-2 summarizes the collective Borda count score for all 15 participants. Note that the most preferred option for the group is Reject (Groundwater) which received a total score of 101 votes based on eight participants choosing Reject (Groundwater) as their most preferred of the eight options, resulting in n (8) points summed 8 times; two participants submitted Reject (Groundwater as their second most preferred option adding n-1 (7) summed twice to the tally; three participants ranked Reject (Groundwater) as their third preferred option for n-2 (6) x 3 points, and one participant ranked Reject (Groundwater) as fourth preferred for n-3 (5) x 1 points. The resulting tally is 64+14+18+5= 101. This process was repeated for each of the eight options in the model.

Table 8-2 Collective Modified Borda Count score for the full set of participants for the Jigs Hollow case study.

Proposal	Rank Placement from left (most preferred) to right (least preferred)								Total Borda Count
	1	2	3	4	5	6	7	8	
Full Approval	0	0	0	0	1	1	3	7	20
Approve (Operational Conditions)	0	0	2	0	5	4	2	0	48
Approve (Timeline Conditions)	1	0	1	2	2	2	5	0	48
Approve (Operational and Timeline Conditions)	0	1	1	5	0	2	1	1	47
Reject (Ground Water)	8	2	3	1	0	0	0	0	101
Reject (Agriculture)	1	3	3	4	2	2	0	1	82
Reject (River)	1	6	2	0	3	0	1	0	76
Reject (Aesthetic)	1	0	2	4	0	2	2	2	52

Collective preference ranking for each group are shown in Table 5-3. Rejection of the proposed amendment is overwhelmingly preferred by all groups. Moreover, this rejection is largely driven by a concern for potential negative impacts to groundwater. Full approval is unanimously least preferred, while reasons for rejecting the amendment and the importance of conditions for acceptance are variable among groups. For instance, rejecting the amendment to protect productive agricultural land is a second preferred option for the local community, while potential negative impacts to the river drives the decision-making for community members living greater than 20 km away from the extraction activities. It is also notable that local participants prioritize operational conditions as being more preferred than timeline conditions, while the opposite is true for the Nearby and Farthest groups.

Table 8-3 Collective preference ranking for each sub-group. Dark shading indicates proposals that are equally preferred.

Group	Collective Ranking from Most preferred (left) to least preferred (right). Shading indicates equally preferred options						
Local	Reject (GW)	Reject (AG)	Reject (AES)	Reject (River)	Approve (OC)	Approve (OC, TC)	Approve (TC)	Full Approval
Nearby	Reject (GW)	Reject (River)	Reject (AG)	Approve (TC)	Reject (AES)	Approve (OC)	Approve (OC, TC)	Full Approval
Farthest	Reject (GW)	Reject (River)	Reject (AG)	Approve (TC)	Approve (OC)	Approve (OC, TC)	Reject (AES)	Full Approval
Full Set	Reject (GW)	Reject (AG)	Reject (River)	Reject (AES)	Approve (OP)	Approve (TC)	Approve (OP, TC)	Full Approval

GW: Groundwater
AG: Agriculture
AES: Aesthetic
OC: Operational Conditions
TC: Timeline Conditions

8-5.2 Discussions and Insights

Several observations can be made from these results. First, the full set of participants greatly prefer that this amendment is rejected, and that decision is driven by a concern about potential negative consequences to local groundwater. If these findings hold true with a larger survey sample, it would be reasonable to recommend rejection of the amendment for any decision-makers who wish to align their policy with public preferences. Concern for groundwater safety remained constant regardless of the distance from the actual impacts of the mine. Findings also indicate that stakeholders seeking avenues to gain support for the amendment can benefit from focusing extra protections and community outreach to address water related concerns. On the other hand, interested parties who wish to justify resistance to the amendment would benefit from framing their messaging around water security issues. It is important to note that the Region of Waterloo relies heavily on groundwater as a drinking source, is the home to Canada's oldest Conservation Authority, the Grand River Conservation Authority, which has been an active advocate for protecting groundwater sources (GRCA, 2014; Veale & Cooke, 2017), and Ontario experienced a devastating groundwater tragedy in 2001, which impacted the entire population of Walkerton Ontario, resulted in seven deaths, and dramatically changed the way that drinking water is managed in the Province (Prudham, 2004). Thus, the inhabitants of Ontario may have an uncharacteristic sensitivity to groundwater issues, indicating that these results could be highly unique to the case study region.

Understanding the perceptions and values that drive decision-making for different groups is invaluable information when targeting potential conditions for amendment approval and communicating to stakeholders after a decision has been made. This is particularly true for decisions that are regulated at different governance and spatial scales, such as developing appropriate messaging efforts to address controversies for both local government and provincial interests. Reducing conflict while approving the amendment could be achieved by placing operational and/or timeline conditions not already included in the amendment plan. Including these conditions represents a viable compromise position while full approval without such conditions is likely to result in enduring resistance to the mining activities. While Local, Nearby and Farthest participants have similar collective preferences, there are some intriguing differences. Preoccupation with the protection of agricultural land and appreciation of the value of an agricultural aesthetic are distinctly centered on participants who live daily within the agricultural community of Woolwich Township.

While the Nearby and Farthest groups can likely imagine the importance of the agricultural land from a pragmatic standpoint, as evidenced by its status as being the third most preferred option for each of these groups, they do not seem to share the aesthetic value of agricultural vistas. For the Nearby group, rejecting the application for aesthetic reasons is less preferred than approving with timeline conditions, and for the Farthest group it is the second least preferred option. It is notable that while these more urban groups would overall prefer to see the amendment rejected, they are resistant to the idea of rejecting it on aesthetic grounds. Thus, there is evidence of a distinct urban - rural divide in aesthetic values of agricultural land. Insights into the identification of appropriate conditions for approval are also available. Note that all groups agree that placing some conditions on the extraction activities is preferable to approving the amendment outright. It is, however, the Local group which will directly experience the impact of such conditions in terms of reduced disruptions over different time scales. In this instance, the Local perception is that operational conditions will better protect their quality of life while the Nearby and Farthest groups both prioritize timeline conditions.

Concluding Remarks

Assessing the environmental and social outcomes from aggregate mining involves value-laden judgments about the distribution of benefits and burdens of development. Participatory approaches can be designed to support the integration and explicit consideration of different values-frameworks in resources management and decision-making. This research has extended the body of knowledge of on-line participatory decision-making for environmental issues by analyzing public input generated using a values-centric approach to online participation, and generating useful recommendations for strategic decision-making. Activating values using online participatory modeling for environmental and resources planning is a new, and relatively untested approach, and as such, methods to organize and integrate individual and aggregated perspectives collected using this method are lacking. This paper demonstrates that a user-friendly and available approach, the Modified Borda Count, readily translates the ranked preferences collected with P2P-DSS into a collective utility preference, generating useful information for decision-making.

While online surveys are convenient, simply collecting 'top three preferences' characteristic of online municipal surveys underutilizes the capacity of emerging computing and online capabilities, representing a loss in terms of social learning, and gaining insights into aspects of decision-problems that contribute to conflict. Citizens who are intimidated to attend or speak in larger group settings may find greater comfort in providing their input in a private setting, with important implications for power dynamics associated with group deliberations, (Barnaud et al., 2006). Thus, online approaches may expand the reach of participatory efforts, and offer opportunities to qualitatively change the experience of participating in group decision-making. One constraint to the adoption of a values-centric DSS is the concern that input collected with the added complexity of values-centric thinking may be difficult to elicit from the pubic, and then to aggregate into usable policy relevant information. Using P2P-DSS adds some complexity to the participatory process, however the ease of ranking proposals from most to least preferred is sufficiently intuitive for most users and represents an improvement to approval voting because insights can be gained about the drivers of the subjects' preferences. Moreover, using a modified Borda Count, the individual surveys are readily translated into collective preferences that can provide insights for decision-making, issue -framing, and conflict resolution purposes.

In this research, the authors have examined preference rankings collected using P2P-DSS, a software program that activates values-centric thinking in an online platform. Using this approach, the roots of resistance to a below-water table mining application are made explicit to both the participants and the researchers resulting in useful information for decision-makers wishing to strategically align their policies with citizen preferences, or to improve public communications. In this case, participant responses indicate clearly that rejecting the proposed amendment is a preferred outcome. However, including extra protections specifically for the local groundwater and surface-water may reduce resistance to the project. While spatial analysis reveals different attitudes towards agricultural aesthetics, participants across all spatial scales prioritized practical considerations, such as water quality over aesthetic concerns. Moreover, for local participants, placing conditions upon the operational activities is more important than timeline conditions. While the sample size in this study is too small to make generalizations applicable to other communities, this work illustrates the type of analysis available using P2P-DSS, illustrating one way that values-centric online contributions can be used as part of comprehensive strategies for formal decision-makers. In this research, the authors expand on past work using P2P-DSS by demonstrating a method to effectively generate collective preferences from the survey responses in order to create useful decision and policy input. For future research, the authors aim to launch surveys with larger participant groups, further exploring the potential for online values-centric platforms to aide participatory decision-making in complex environmental issues.

Chapter 9

Identifying Potential Conflict in Land-use Planning Using P2P-DSS.

Highly regulated environmental management decisions require consideration of multiple stakeholders with different sets of knowledge, values, and expectations of the decision outcome (Keeney & McDaniels, 2001; Pahl-Wostl et al., 2007; Petts & Brooks, 2006; Taylor & de Loë, 2012). With individuals and groups having such different backgrounds it can be challenging for decision-makers to identify conflicts in advance in order to manage them proactively. However, conflict prediction merits serious attention, particularly on issues of land-use where disputes are sufficiently ubiquitous that the goal is not to avoid conflict altogether, but to manage it as a feature for creative group decision-making rather than a source of violence or resources draining litigation (Brown & Raymond, 2014). As such, methods to harness understanding of conflicting perspectives and priorities have been developed including the use of spatial decision support (Brown et al., 2017), game theoretic models (Xu et al., 2018), cognitive-affective mapping (Thagard, 2010), and the policy Delphi approach (De Loe, 1995; de Loë, Melnychuk, Murray, & Plummer, 2016; Needham & de Loë, 1990).

In the following chapter, a method to study conflict using the P2P-DSS survey approach is presented. The manuscript presented in Chapter 10 proposes and demonstrates a new technique for studying and predicting values conflicts using P2P-DSS. In so doing, Chapter 10 addresses research objective 3: "Evaluate the values-based data collected and examine potential contributions of this dataset to understanding values-based conflicts". This work is situated within the Digital Government literature, known as *e*-government, and Conflict Studies. Specifically, the contribution of the manuscript included in Chapter 10 is in generating a qualitatively new experience for citizens as they contribute input in an online participatory process, that of interactive values-based modeling. Moreover, this technique creates a novel dataset that is poised to make unique contributions to conflict prediction and management.

The manuscript included in this dissertation as Chapter 10 describes the operation and use of a specific interactive element in P2P-DSS known as the 'protest function'. This element allows an individual to change an aspect of the expert model – the input connecting the choice of a specific option to a selected value, and the weight (importance) that the value has over selection of the focal option. Giving users access to the editing feature used to integrate values into the model serves to make the model assumptions explicit, thereby communicating to users the values that informed the model and providing a tool for communicating their own values-beliefs back into the model.

The number of protests connecting the two dimensions are recorded, and measured independently or in combination with inputs from other users to gain insights into differences between individual and groups perspectives over the decision. Identifying aspects of conflicts for which various stakeholders do not have a shared understanding of their own values, and how specific outcomes will impact their respective values, provides an advantage in terms of anticipating conflict potential and tailoring management approaches to relevant challenges.

The manuscript included as Chapter 10 of this thesis has been published in the peer reviewed proceedings of the 52nd Hawaii International Conference on System Sciences (HICSS), 2019 (Philpot et al., 2019c). The original manuscript published in the HICSS 2019 proceedings has been expanded as part of preparation for submission for journal publication.

Chapter 10

Identifying Potential Conflict in Land-use Planning Using a Values-centered *e*-Participation Tool.

Chapter 10 is a manuscript published in the peer-reviewed proceedings of the 52nd Hawaii International Conference on System Sciences in 2019. The manuscript has been updated to reflect changes made in preparation for submission for publication in an academic journal. The version of this paper as it is published in the hicss-52 2019 peer-reviewed proceedings can be found using the following citation:

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Philpot S.L.[a], Hipel K.W.[bcd], Johnson P.A.[a]
[a] Department of Geography and Environmental Management, University of Waterloo, Canada.
[b]Department of Systems Design Engineering, University of Waterloo, Canada.
[c] Centre for International Governance Innovation, Waterloo, Canada.
[d] Balsillie School of International Affairs, Waterloo, Canada.

Abstract:

An innovative *e*-participation tool used to facilitate the articulate of values-laden assumptions and to identify key points of likely conflict is illustrated using a real-world example from an aggregate mining controversy in Ontario, Canada. The decision model developed using the 'Public to Public Decision Support System' (P2P-DSS) reflects a perspective that differs from participant perceptions in terms of the social values that influence rejection of a permit amendment application. This work proposes that by facilitating two-way communication about values assumptions, P2P-DSS generates a novel dataset that can support pro-active conflict management and contribute to a shared understanding between formal decision-makers and citizens.

Keywords: Conflict, Prediction, Values, Modeling, *e*-participation

10-1 Introduction

Consideration of public preferences is a key aspect of democratic decision-making and planning (Lourenço & Costa, 2007; UNECE, 1998). For some citizens, providing input online reduces barriers to participation, particularly when mobility, travel costs, motivation and opportunity costs pose restrictive burdens to engaging in traditional participatory processes (Wagner, Vogt, & Kabst, 2016). The significance of online participation, or e-participation is sure to rise in-step with increased access to high-speed internet (Browning, 2002; Canadian Radio-Television and Telecommunications Commission (CRTC)).

Typically, municipalities use e-participation tools that replicate aspects of real-world services into online spaces, increasing service delivery efficiency (D 'agostino et al., 2011). However, with advancements in Information and Communications Technology (ICT) design features unique to online spaces can be leveraged to add innovative services and generate new datasets for informing decisions (Grönlund, 2004; Johnson et al., 2015; Lourenço & Costa, 2007). These new types of information can then be harnessed to inform policy-making on critical social issues. Fostering and understanding the novel opportunities presented by ICT is a focus of scholarship in Government 3.0. This field of study examines the evolution and implementation of ICT that move beyond services efficiency goals characterized as Government 1.0 and the use of social media to promote participation and transparency between government and citizens of Government 2.0. While Government 3.0 expands into new and transformative technologies including tools that engage in societal simulation to provide new services and value to citizens, the use of technology to customize services, and leveraging technology to facilitate collaborative and co-creative decision-making (Loukis, Charalabidis, & Flak, 2019), concerns with efficiency, cost effectiveness and accessibility remain priorities (Park & Lee, 2015; Song, 2014).

This paper proposes that advancements in values-based participatory modeling and online decision support can facilitate the sharing of perspectives and information between formal decision-makers and citizens. The authors present an illustrative example in which an online platform, P2P-DSS is used to make values assumptions explicit and to identify potential values conflicts between formal decision-makers and users. This technique can be used to develop strategic insights that may be useful for government agencies and professional decision-makers who wish to use *e*-participation to better understand citizen perspectives on controversial decisions and to pro-actively manage conflicts that are rooted in different values frameworks or perceptions.

10-2 Harnessing Values for Conflict Management and Decision-making

Section 10-2 provides an operational definition of values grounded in the fields of personality and social psychology. It also situates values research into conflict studies by examining the role of values in disputes. Next, this section summarizes relevant advancements in integrating values into decision-making. Finally, Section 10-2 discusses previous work in the prediction of conflict using participatory modeling and electronic participation (*e*-participation) techniques.

The Role of Values in Decision-making and Conflict

Interpersonal conflicts arise when the physical presence of an individual, a group, or an activity, impinges on the expectations, goals, or well-being of another individual or group (Vaske, Needham & Robert, & Cline, 2007). Social values conflicts, on the other hand, arise from disagreements over values, and require no physical contact between groups. Disputes can also combine interpersonal and values conflicts, with individual or group actors both impacted directly by another decision-maker's actions, and opposed to the action because it threatens a prioritized value (Vaske et al., 2007).

Values are distinct from and foundational to various emergent psychological phenomena with which they are often conflated (Schwartz, 2012), such deeply held beliefs are evaluative, motivational, and linked to affect. Some are complementary, meaning that outcomes that support one value have a positive impact on a closely related one. Other values are contradictory, meaning that achieving a goal associated with a focal value comes at a cost to another. In the latter case, value trade-offs are necessary when deciding on a course of action or preferred outcome (Schwartz, 2012; Schwartz & Bilsky, 1987). Characteristics that distinguish interpersonal from values conflicts include that values are trans-situational, while goals in interpersonal conflicts are context specific, goals are frequently articulated explicitly, while values typically influence decision-making outside of conscious awareness, and goals, knowledge, and options can be readily changed, but values are deeply held and thus more stable in the absence of facilitated and conscious effort (Roccas, Sagiv, & Navon, 2017; Schwartz, 2017). Finally, while decision-makers may have uneven access to information or opposing goals, values seem to be universally held (Keeney, 1992; Schwartz, 2012; Schwartz & Bilsky, 1987).

While everyone has values, the relative importance of specific values, known as a values framework, varies between individuals and groups and differences in these frameworks can lead to conflict (Schwartz & Bilsky, 1987). Distinguishing between instrumental (based on cost-benefit analysis) decision-making and values-based decision-making is also crucial, particularly when values are perceived to be sacred (Ginges, Atran, Medin, & Shikaki, 2007). Not managing the influence of sacred values can exacerbate conflict if compromises based in instrumental incentives are proposed where values- based decisions are relevant (Ginges et al., 2007).

While conflict can arise from different values frameworks, explicitly addressing values in decision- making leads participants to be more satisfied with decision outcomes, results in social learning, and can achieve some goals of participatory decision-making (Bessette et al., 2016; Keeney, 1992; Morais et al., 2013); it is thus a robust area of study in the decision sciences (Keeney, 1992) and environmental management (Dietz et al., 2005). Values research has the potential to improve outcomes in regulated environmental management conflicts through the development of facilitated approaches to address values frameworks while connecting governments, regulatory bodies, and citizens on issues of shared interest (Glenna, 2010).

Integrating Values in Planning and Decision- making

Integrating citizen values for participatory planning is facilitated by numerous techniques. Fuzzy Cognitive Mapping (FCM) can be used to develop common understandings of complex systems, support the exchange of information and foster co-operation between stakeholder groups (Giordano, Passarella, & Vurro, 2010). FCM approaches model the behavior of interrelated systems from the perspective of any individual or group (Groumpos, 2010). On a Fuzzy Cognitive Map, concepts are graphically represented as nodes, for which causal relationships to other nodes are represented with weighted arcs. As nodes can represent any type of concept, including physical phenomena, events, actions, or values, this method can be used to investigate social dynamics in complex planning issues (Giordano et al., 2010). FCM has been used to support participatory natural resources management (Hjortsø, 2004; Özesmi & Özesmi, 2003) group decisions (Khan & Quaddus, 2004) and Integrated Ecosystem Management (Vasslides & Jensen, 2016). However, creating a Fuzzy Cognitive Map requires in-person interviews or workshops. Participants must sufficiently grasp system dynamics to feel confident generating a map, and the task adds time and budgetary burdens to existing planning procedures. Moreover, aggregation of individual FCMs into a group perspective relies on experts to simplify data by representing only the variables that are most often identified (Kok, 2009). These drawbacks can limit the ability for non-experts to participate in FCM approaches, reduce the information collected from each participant, and constrain institutional up-take of FCM activities (Kok, 2009). Thagard (2010) developed Emphatica, a computer assisted method to generate cognitive-affective maps that captures the relationships between emotion and values associated with interconnected concepts. While proposed for use in conflict resolution (Thagard, 2010), Thagard (2014) used this technique to teach undergraduate students in medical and environmental ethics courses. Post-use evaluations by the students indicate that this method led many students to change their minds regarding issues they modeled and found it to be a useful way to learn about ethics (Thagard, 2014).

Another method, Public Participation Geographic Information Systems (PPGISs) integrates values data in a spatially explicit format, and can be useful for identifying conflict potential. PPGIS techniques can be operationalized for analytic purposes in Spatial Decision Support Systems (SDSS). For instance, Cerreta & Mele, (2012) used a SDSS to integrate local community values and expert knowledge into decision-making frameworks for strategic planning. Brown, (2006) used participatory GIS to better understand local preferences for tourism and development planning. Participatory mapping of values was used by Brown & Raymond, (2014) and Brown et al., (2017) to assess conflict potential in land-use planning, and PPGIS surveys were used by Munro et al., (2017) to understand stakeholder values for marine and coastal areas planning and management.

Identifying Conflict Potential with e- Participation

Conflicts may emerge when actors hold incompatible values frameworks that impact their perception of a decision context and their preferences. Alternatively, actors may disagree about how specific outcomes will impact prioritized values. Depending on the source and nature of disagreement conflicts may be minor and easily resolved or involve protracted and heated disputes (Brown et al., 2017). Anticipating conflict provides formal decision- makers with opportunities to proactively target management strategies and to respond to stakeholder concerns. Early identification of conflict potential enables government actors to allocate social resources and facilitate communication between stakeholder groups (Brown & Raymond, 2014) reducing the likelihood of long-term legal costs and improving relations between government decision-makers and citizens.

Conflict prediction has thus been applied to various environmental cases under regulatory purview. Participatory mapping was used by Brown et al., (2017) to identify conflict potential in seven environmental and natural resources sites, and by Karimi & Brown, (2017) to identify potential conflict loci in development, mining, and land- use decisions. Moreover, potential disputes rooted in conflicting participant perspectives have been identified by combining multiple FCMs (Giordano et al., 2010).

Herein, the authors examine the collection of values data from experts and citizens using a novel participatory values-based modeling approach. The online software program, Public to Public Decision Support System (P2P-DSS) uses interactive tools and visual cues in a shared modeling space. Values data input by participants is analyzed to identify clusters of disagreement about the values-laden assumptions of formal decision-makers and citizen participants. Clusters of disagreement, known as 'protests' are interpreted as hot-spots for potential conflict because they emerge from elements of a decision for which stakeholders do not share a common view.

10-2.0 Current Research

Section 10-2 summarizes the current research presented in this paper. First, in Section 10-2.1, a conceptual framework proposes the existence of a meaningful connection between protest clusters collected with P2P-DSS and the potential for values-based conflicts. Section 10-2.2 describes a real-world example that was used to frame the current study into protests clusters and provides an overview of how the P2P-DSS decision support system is used. Section 10-2.3 then describes the methodology used in this research. Study results are summarized and discussed in section 10-2.4.

10-2.1 Conceptual Framework

Opportunities for conflict to have creative and even beneficial influences over decision-making are premised on a definition of conflict that is not restricted to violent interactions. Herein, the definition of conflict includes not just violent disputes, but also all manifestations of "*incompatibilities of positions*" held between and within individuals and groups (Bercovitch et al., 2009:3). This definition then, captures the sources, positions, and processes of conflict evolution and development. With this lens, conflict can be seen as a ubiquitous and normal feature of human interaction that can be harnessed to enhance decision-making processes (Bercovitch et al., 2009).

When a conflict arises and is recognized, its source is not always clearly understood, a circumstance that can complicate management efforts. In the following study a new technique for analyzing conflicts is proposed using the new participatory modeling platform, P2P-DSS. To better understand the drivers of values-based conflicts, this manuscript describes how P2P-DSS operationalizes a new conceptual model for conflicts (Figure 9-1), which is used to characterize conflict potential as a function of values-options protests input by P2P-DSS users. This approach is described with reference to the Jigs Hollow aggregate mining conflict.

To anticipate conflicts and proactively manage their outcomes, be it by prevention, mitigation or finding peaceful resolutions, their underlying drivers must be understood. For instance, in a land-use dispute, planners, local business owners, municipal government actors, and citizens may not agree about how a disruptive land use activity will impact the aesthetic character of a community. Disagreements may arise because of the different ways that people will experience the impacts (Sarewitz, 2004), for example, one stakeholder may welcome an urbanization project that modernizes the landscape and view the changes as positive, while another may view this change as a threat to aspects of the community that they value aesthetically. Alternatively, conflict may be rooted in differing values frameworks, in which case, stakeholders may agree on the impacts, but not on their importance. For example, while a business owner and a community member may agree that a land-use change is negative for aesthetic reasons, they may not equally prioritize aesthetics in terms of making decisions. Finally, there may be a lack of shared trust and belief in the likely outcomes of an activity in the first place.

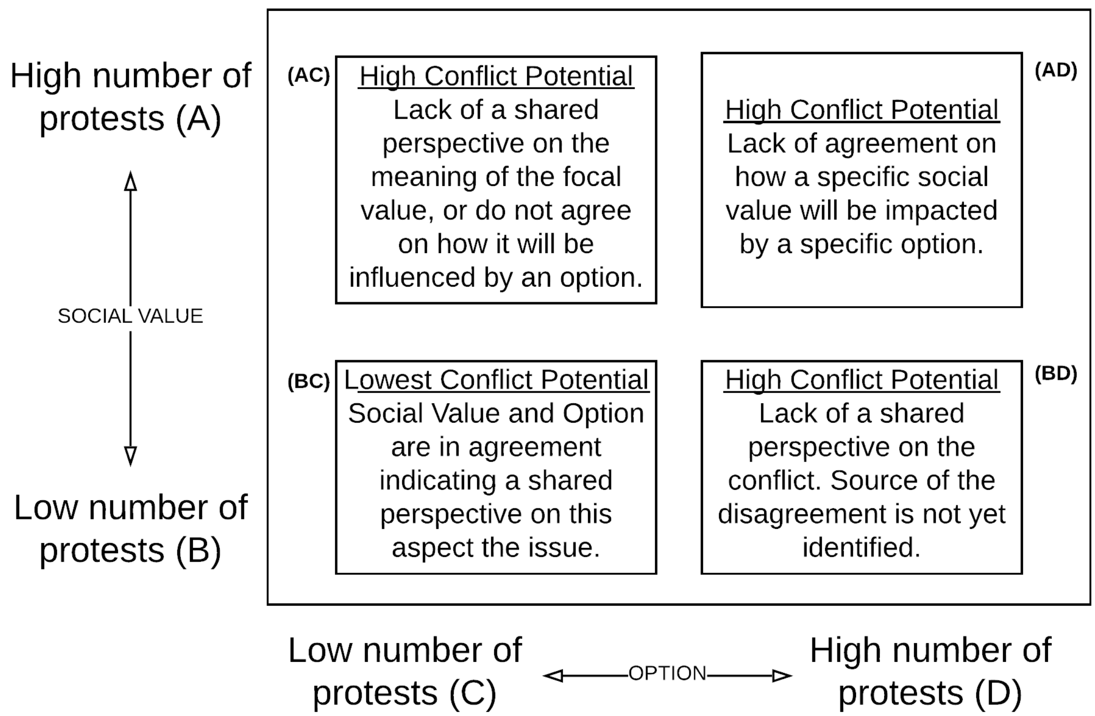

Figure 10-1 Conflict potential as a function of values and options protests as recorded using P2P-DSS. When observing user protests during participatory interaction with the P2P-DSS system.

Each of these drivers of conflict call for a different management response. For the latter example, bringing in experts or communicating scientific understandings across the stakeholder groups may be effective, whereas, compensation or mitigating actions could reduce the impacts to disproportionately burdened groups if differing experiences of the impacts of the action are fueling tensions. In some values-based conflicts, offering such dispensation may drive conflict escalation (Atran, Axelrod, & Davis, 2007; Ginges et al., 2007; Hanselmann & Tanner, 2008). Thus, for different dispute drivers, a different set of conflict management techniques may be appropriate, however the source or sources of conflict must first be understood.

10-2.2 Illustrative Application of P2P-DSS

Conflicts frequently arise when land-use activities have the potential to negatively impact aspects of the social or physical environment, and when the trade-offs between competing uses are viewed differently by individuals or groups (Brown et al., 2017). These conflicts are particularly difficult to manage when the competing perspectives center around differing social values frameworks. In these challenging contexts, multiple government and regulatory decision-makers are tasked with making decisions that distribute the benefits and burdens of development across time and space (Government of Ontario, 2014.). Developing ways to anticipate the conditions that are likely to lead to conflict can provide professionals with information to minimize controversy, costs, and delay, through strategic communications, pro-active responses to citizen concerns, and conflict management (Brown et al., 2017).

Aggregate Mining

Clays, rocks, sands and marls, collectively known as aggregates, are a foundational input for modern living, providing the key ingredients for urban infrastructures. The mining of aggregates is of public interest both because of what can be built and because of the conflicts that frequently result from their extraction. While the beneficial outcomes from urban living are widespread, the impacts of aggregate extraction are highly localized, and since aggregates must be mined where they are found, the locations are inflexible (Keeling & Sandlos, 2009; Van Wagner, 2016). These qualities make decision-making about competing land-use options in aggregate rich regions particularly prone to controversy, as the competing needs of regional governments, local communities and dependent industries conflict. Resistance to extraction activities can be characterized as a 'Not In My Backyard' (NIMBY) reaction (Pelekasi, Menegaki, & Damigos, 2012), however this description risks unfairly dismissing legitimate concerns of impacted citizens to important asymmetries in the distribution of the benefits and burdens of urban development. Seeking greater understanding of how disparate values generate controversy in these cases is an important step towards managing conflicts for more creative and democratic decision-making.

Study Site

The Township of Woolwich (Woolwich) is located in the Region of Waterloo in Ontario, Canada. Woolwich has an approximate population of 25,000, across 10 small communities. It is a rural region with a strong agricultural economy (Census Canada, 2019; “Township of Woolwich,” 2016). In 2012 Preston Sand & Gravel Company (Preston) received approval to extract aggregates from an approximately 36 hectares site known as Jigs Hollow pit (IBI Group, 2016). The existing permit restricts Preston to extraction with a 1.5meter buffer above the groundwater table. In 2014, it became clear that the water table was higher than expected and Preston initiated efforts to amend the permit to allow below-water-table extraction (IBI Group, 2016).

The amendment application has generated considerable controversy related to a variety of citizen concerns (“Elmira Advocate,” 2016; Latif, 2017). For instance, below-water-table extraction has a larger impact on the immediate activities at the site as well as generating long term landscape changes. Large and more invasive equipment is required, meaning that daily operations may be more disruptive to the local community, and unlike the 2012 permit which required Preston to restore the site to its agricultural quality following the end of mining activities, this is not possible for below-water-table extraction, and the land would instead be transformed into a naturalized lake (IBI Group, 2016).

Exploring the Jigs Hollow Conflict with Participatory Values-centered Support

P2P-DSS is an online interactive participatory modeling software program. Formal decision-makers can use P2P- DSS to create a model of a decision or issue from their own perspective, and that model can be used as the basis for collecting input about preferred decision outcomes. In 2017 the authors evaluated the process of using P2P-DSS to collect values-based input about an environmental decision. In order to integrate realistic constraints into the model and to involve potential users in system evaluation, the test centered on the real-world Jigs Hollow example. For this test the authors recruited a confidential volunteer who had a formal role over the Jigs Hollow decision and a professional level of expertise on the issue. The decision-maker built a model of the decision problem using a process described below and in Philpot et al. (2019a; 2019b). Fifteen volunteers were then recruited to use and evaluate P2P-DSS, these steps are outlined in section 10-3.1.

Over the course of two meetings a formal decision- maker (F-DM) with a professional interest and expertise in the Jigs Hollow amendment built a model of the decision context. The model consists of relevant contextual information, available options, and a values-framework that expresses which social values motivate selection of a focal option. The process of model development and algorithms that are used to operationalize the website features are described in detail in chapter 6. This section briefly reviews the steps taken to build a P2P-DSS model, with reference to the model developed of the Jigs Hollow decision.

Three options to accept the amendment were included in the F-DM model: (1) accepting the amendment as it was proposed by Preston (2) accepting the amendment but adding operational conditions to limit the day to day impacts of mining activities on local citizens and (3) accepting the amendment but adding timeline conditions on the extraction activities. In order to probe the drivers of public resistance to the project the model included four options to reject the amendment, each addressing a feasible public concern: (4) rejection of the amendment due to concerns about groundwater (5) rejection of the amendment to avoid potential negative impacts to surface water (6) rejection for protection of prime agricultural land and (7) rejection based on a desire to preserve the heritage and aesthetic value of the rural landscape.

Using an interactive feature designed specifically for this purpose, the F-DM embedded in the model an expression of what social values would likely motivate an individual to choose each option (Figure 10-2). Ten values were provided in the model template, and as the F-DM created options, they also selected the values that they believed were important to that option. The F-DM calibrated how important that value was by moving a slider feature from the left (less important) to the right (more important). For example, in Figure 10-2 the F-DM has made explicit their assumption that choosing to reject the amendment based on concerns about negative impacts to groundwater is motivated by a values framework that prioritizes environmental protection and security, with environmental protection dominating the choice. The remaining eight values are considered irrelevant to this selection.

The F-DM then created proposals by combining options. Proposals can include single options or feasible combinations of options, and are decision outcomes under consideration. The weighted values associated with each option on a proposal are then combined to create a values framework for that focal proposal (Philpot et al., 2019a). In the Jigs Hollow model, the F-DM identified eight proposals in total that they considered to be potential outcomes for consideration. Seven of these proposals were created with only one option and therefore were identical to the options listed above. One of the proposals combined two options such that accepting the amendment with both timeline and operational considerations added was under consideration. More combinations were possible with this model; for instance, it is possible to reject the amendment to protect both groundwater and surface water, rather than for one single reason. The F-DM did not choose to create those proposals during the modeling process, leaving it to public participants to create further proposals if they were so inclined during the participatory process.

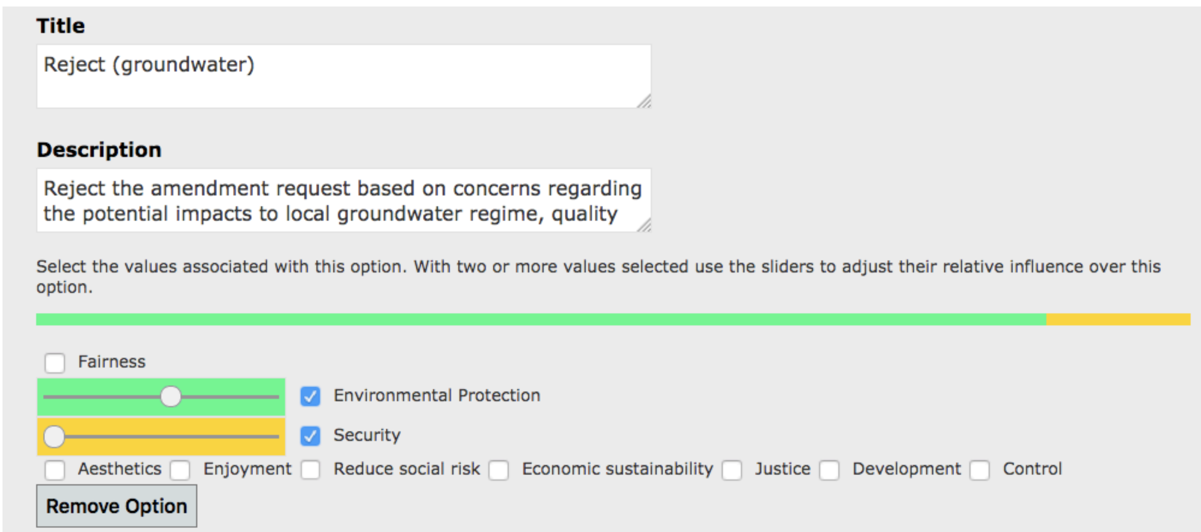

Figure 10-2 Values embedding feature showing the social values associated with the Reject (groundwater) option in the Jigs Hollow expert model.

Using P2P-DSS, participants who wish to provide input to decision-makers first rank the proposals from most to least preferred by moving proposals displayed on the graphical user interface from left (most preferred) to right (least preferred). After submitting a first ranking, the user is shown a pie chart, known as the 'mirror', that summarizes their values framework derived by combining the values assumptions embedded by the expert with the ranking submitted by the public participant (Philpot et al., 2019a). If the ranking and the values mirror are both consistent with the user's self-perception and preferences, they are invited to re-submit the preference ranking as is, thereby providing the formal decision-maker with preference information about the full spectrum of proposals under consideration.

If, however, the user feels that their values are not reflected in the mirror, they can change the values framework using a variety of interactive features. The user can re-rank their preferences, create new proposals and add them to the ranking, and they can change values assumptions that were previously provided by the expert. The latter function is known as a values protest, and it allows the participant to reconcile their preferences and values input without changing the proposal rankings. All of these interactions result in real-time changes to the values mirror in order to support the user in creating a proposal ranking that harmonizes with their values before submitting their final input.

In 2017, 15 participants provided their input on the Jigs Hollow amendment application using P2P-DSS. The submitted preferences rankings are analyzed in Chapter 8. These volunteers also completed a written survey about their experience using the system, the results of which are discussed in Chapter 8. Similarly, an overview of the broader research project and system parameters, which is beyond the scope of this paper, is provided in chapter 6.

10-2.3 Methods

In 2017, the authors recruited study participants from the Woolwich Township and surrounding communities using local newspaper advertisements, social media, snowball recruitment methods, and email lists at the University of Waterloo. Ultimately, fifteen participants volunteered to take part in the study. Five of the participants identified themselves as being residents in or near Woolwich community, while ten were residents of Kitchener, Waterloo, Mississauga, and Toronto, Ontario. The latter ten volunteers identified as University students. Each of the volunteers used P2P- DSS to provide their input on the Jigs Hollow mining amendment proposal in a controlled laboratory setting.

Participants were given brief instructions on how to use the interactive elements to learn about the amendment, create proposals, rank proposals from most to least preferred, and protest the values assumptions that were embedded in the expert model. P2P-DSS recorded every interaction with time stamps, including movement of proposals, proposal creation, and values protests. After using the system, the volunteers completed a written survey about their perceptions and experience using P2P-DSS, which have been summarized in Chapter 6, and an in-depth analysis of the submitted proposal rankings is provided in

Chapter 8. This paper will focus on responses from participants who chose to alter the model parameters by changing the options-values associations originally input by the F-DM.

After clicking on the ‘protest this value button’ (Figure 10-2), values protests involve three possible interactions. First, if the formal decision-maker (F-DM) did not model a focal value as relevant to the selection of a specific option, the participant can protest that assumption by adding a check mark to the box beside the value. Second if the F-DM modeled a focal value as relevant to the selection of a specific option, and the participant disagrees with this assumption, it can be deselected by removing the check mark. In the first case the influence of a value for that option is changed from a weight of ‘0’ to a weight of ‘1’. In the second case the weight is changed from ‘1’ to ‘0’. Once selected, the influence of the value can also be changed by moving a slider feature to the left to reduce the relative weight of the focal value and to the right to increase the weight. Compare Figure 10-2 to Figure 10-4; the values associated with rejecting the amendment due to concerns about groundwater impacts have been protested and altered to include reduction of social risk and control as motivating values, with reduction of social values being equal to environmental protection, and control weighted at 1. The precise numerical weight assigned to a value is relative to the full spectrum of values associated with the option and is determined using an algorithm described in Appendix A.

The P2P-DSS database records each protest including the original weight assigned to the value and subsequent weights selected as the user interacts with the slider-feature. The authors aggregated the protests associated with options and values to identify aspects of the decision problem for which the expert model and participant perspectives diverged.

Figure 10-3 Image from P2P-DSS interface showing the button used to access the 'values protest' option and the values framework 'mirror' that interactively adjust in response to changes to the modeling parameters.

Figure 10-4 Image seen by participants who select the values protest element for the Reject (groundwater) option. By selecting and deselecting values with check marked boxes and changing the influence (weight) of selected values using the slider element, users interact with and can change the values assumptions embedded by the formal decision-maker.

10-2.4 Results

Seven participants protested one or more options-values assumptions. All of the protests originated from participants who lived within 20km of the Jigs Hollow site. A total of 36 protests were recorded, with an additional two protest interactions that resulted in the participant calibrating the values assumptions to their original state, resulting in no change to the model. The protests that did not result in a model change are important as they demonstrate that the participant is exploring how their values interact with the options, however only protests that resulted in a change are considered in this analysis.

The number of protests varied greatly across participants with one participant registering a single protest, two participants submitting two protests each, one participant protesting four assumptions, one participant submitting eight protests, another inputting nine protests, and a final participant submitting 10 protests.

The protests collected for each option, the values that were the focus of the protests, and the original and new weights for each value are shown in Table 10-1. The only option to receive zero protests is to accept the amendment. Rejecting the amendment to protect agriculturally productive land received the highest number of protests.

Patterns of protest can indicate aspects of the decision problem for which the formal decision-maker and public participants do not have a shared view of the issue. This approach is similar to combining FCMs (Giordano et al., 2010) or analyzing spatially embedded values data (Brown & Raymond, 2014), however it does not require the analyst to discard any inputs provided by the participants, nor is there a requirement for participants to learn complex problem structuring or mapping techniques. In this section, observations from the collected protests are discussed. The reader should bear in mind that the intention in using an illustrative example is to highlight and demonstrate the types of insights made available with this method. This study involved a participant group of 15 individuals, and these results are not intended to be generalized to any larger group or community.

The lack of protests for ‘accept’ can be interpreted in two ways. First, the participants may agree with the original calibration of the expert model in which ‘accept’ was motivated in equal measure by values associated with development and economic sustainability. It is also possible, however, that acceptance was sufficiently unpopular that participants did not explore the values that drive this option, focusing more on options that were under consideration for more preferred positioning.

The values calibrated for rejection of the amendment to protect high quality agricultural land have the highest potential for conflict because the greatest number of values are protested for this option. The participants inputs seem to connect the protection of agricultural land with environmental protection, reducing social risk and providing greater security, whereas the F-DM did not model these values as relevant. While the F-DM did associate this option with development and economic sustainability, the protests indicate that they have a greater influence for the participants than that reflected in the model created by the F-DM.

Table 10-1 Summary of values-assumptions protests collected in the P2P-DSS study.

Option	Value protested	Change to value calibration weight
Accept	-------	
Accept (timeline)	Development	Increase from 1 to 8
	Economic sustainability	Decrease from 4 to 2
	Environmental Protection	Increase from 0 to 1 Increase from 0 to 4
	Fairness	Decrease from 4 to 2
Accept (operational)	Environmental protection	Increase from 0 to 1
	Fairness	Decrease from 4 to 0 Decrease from 3 to 1
Reject (Groundwater)	Control	Increase from 0 to 6
	Economic sustainability	Increase from 0 to 1
	Environmental Protection	Increase from 7 to 10 Increase from 7 to 11
	Security	Increase from 1 to 4 Increase from 1 to 7
Reject (River)	Enjoyment	Increase from 1 to 2 Decrease from 1 to 0
	Environmental Protection	Increase from 7 to 10 Increase from 7 to 10
	Fairness	Increase from 0 to 1
	Security	Increase from 0 to 1 Increase from 0 to 1
Reject (Agricuture)	Development	Increase from 1 to 2 Increase from 1 to 7
	Economic sustainability	Increase from 1 o 3 Increase from 1 to 2
	Environmental protection	Increase from 0 to 1 Increase from 0 to 2 Increase from 0 to 9
	Reduce social risk	Increase from 0 to 1
	Security	Increase from 0 to 1 Increase from 0 to 3
Reject (Aesthetic)	Aesthetic	Increase from 0 to 1
	Enjoyment	Increase from 5 to 8 Increase from 5 to 8
	Economic sustainability	Increase from 0 to 1
	Environmental protection	Decrease from 8 to 0
	Fairness	Increase from 5 to 8

Patterns of protests make values assumptions explicit and thereby available for interpretation and study. For instance, in the Jigs Hollow illustration, protecting the rural aesthetic landscape is associated with aesthetic values and economic sustainability for participants but not for the F-DM. Associating the rural landscape with positive aesthetics can be interpreted in many ways that could highlight subjects that would benefit from further study as part of a conflict management strategy. For example, it may reflect a place attachment that would suffer in light of aesthetic change. Associating this option with economic sustainability may reflect a belief that heritage and farm aesthetics have positive impacts on rural tourism and the popularity of the local farmers' market economy. Protests that reduced or eliminated values associations are also informative. First, the formal decision-maker characterized the inclusion of timeline conditions as positively correlated with fairness values. One participant viewed this association as overstated, reducing its impact. In the case of rejection for aesthetic reasons, the formal decision-maker strongly correlated this option with protection of the environment, whereas a protest interaction removed the association entirely. These interpretations are not intended to be definitive but illustrate the types of observations and questions that may be raised by the data generated using P2P-DSS. Drawing upon these questions could inform further examinations of participant perspectives as they identify incongruities in perceptions between the F-DM and participants that may warrant further study.

By examining the protests recorded, clusters can be identified, making explicit instances in which a lack of shared understanding about specific aspects of the decision problem could lead to conflict. Moreover, analysis of the values that are protested, and the changes recorded can better inform decision-makers about where their own perspectives are not shared with the public. In the Jigs Hollow example, the research participants have a different view of what motivates rejection of the amendment, particularly in terms of protecting agricultural landscapes. It is notable that, for the most part, the public participant protests are similar in the direction of change. The only instance in which participants moved a value assumption in different directions was the association between rejection for river protection and enjoyment.

10-3 Discussion and Limitations

This research summarizes a study using P2P- DSS to identify protest clusters as a source of information related to the existence of values-conflicts. Just as fuzzy cognitive maps can be combined to identify differences in stakeholder perspectives (Giordano et al., 2010; Groumpos, 2010), values protests collected using the P2P-DSS approach can be compared to identify differences in values assumptions about a decision. This paper describes an application of using P2P-DSS to predict conflict and discuss the potential applications of this information for informing decision-making and communications strategies for issues of public interest. However, it reports on only a small group of participants. Due to the novelty of the program and the limited size of the participant group used in this study further studies are needed with larger participant groups in order to further understand the protest patterns that emerge using this program.

By leveraging the interactive features of modern ICT, values are operationalized resulting in a new dataset for informing decision-making. This work is in stark contrast to e-government literature emphasizing efficiency of services delivery (D 'agostino et al., 2011; Song, 2014; Vicente & Novo, 2014) stressing instead, the transformative potential of *e*-government (Loukis et al., 2019). P2P-DSS intentionally slows down the process of providing online input. By creating an opportunity to interact with the model parameters P2P-DSS delays the process of providing online input on an issue, and generates a new type of co-created information; Specifically, values protests are generated that can then be compared for conflict prediction. As a new approach, it remains to be seen how this intentional slowing down of a process will be received within the *e*-government community. Thus, one area of research that needs further development is conducting long term studies of the up-take of P2P-DSS values-protests. Future research should examine the opportunities and constraints for integrating this approach into formal decision- making. By proposing the framework for generating and analyzing values protests, this paper prepares a foundation for the additional work that is needed to understand the potential for P2P-DSS to make practical and theoretical contributions to real-world decision-making.

Chapter 11
Conclusions, Challenges, and Future Research Directions

11.1 Concluding Remarks

This dissertation addressed the difficulties to participatory environmental management posed by the importance of values trade-offs when thinking through environmental decisions. To support the development of flexible and accessible techniques for thinking through values this dissertation proposed, designed, implemented, and tested a proto-type software program to operationalize values in a participatory modeling environment. The user interface, Public to Public Decision Support System (P2P-DSS), incorporates an interactive program for eliciting preferences while prompting users to explore how their preferences are driven by their values. In short, the program makes an unconscious motivator – values - conscious, such that their influence over decision-making is no longer reflexive, but reflective. This approach will prove useful in expanding our understanding of how values can be operationalized to enhance participatory environmental management.

In seeking to support values-based thinking in participatory environmental management, this work has made several methodological and theoretical contributions to scholarship. First, the preference ranking technique used in the Graph Model for Conflict Resolution (GMCR) approach is expanded such that the underlying values informing preferences are made explicit. This technique will be useful for future studies integrating values-based decision-making and conflict analysis. For example, previous work incorporating a values-based approach into GMCR currently utilizes publicly available documentation to identify and organize participants and their objectives (Williams & Fang, 2018). P2P-DSS could expand the reach of that methodology by facilitating the collection of values-input through online surveys. This would reduce reliance on researcher interpretation of recorded statements and may increase the number of participants whose values are integrated into models.

Second, this work indicates that participants may not always need to learn formal problem structuring techniques in order to engage in values-based decision-making. Decision Analysis emphasizes the importance of following systematic procedures in the assessment of complex decisions (Keeney, 1982). For example, in value-focused thinking participants are guided through novel problem structuring techniques by skilled facilitators. This limits the reach of value-focused thinking opportunities to leverage the accessibility of online environments because of the cognitive cost to participants when problem structuring techniques are translated into software environments (Bessette et al., 2016). While studies in the application of values activation to a range of participatory settings are needed, this dissertation indicates that simply activating values using software feedback can achieve some of the goals of values-based participation.

Third, this is, to the authors knowledge, the first study in which values activation has been studied as a way to support participatory decision-making. Studies have demonstrated the influence of values activation over emergent psychological properties, such as sense of well-being (Boer, 2017) and behavior (Schwartz, 2017), and some studies have used experimental approaches to study how software feedback can cause values activation that ultimately influences decision-making (Hosack, 2007; Hosack & Paradice, 2014; Rokeach, 1975). In testing the prototype system P2P-DSS using a realistic scenario this thesis has examined how values activation can be applied prescriptively to expand the reach of values-based decision-making to online participation, and laid the groundwork for future applications using real-world case studies.

11.2 Summary of The Thesis and Overall Contributions

11.2.1 Summary and Concluding Thoughts Related to Values Research

Integrating values into this interdisciplinary research raised interesting challenges that ultimately informed the direction of this thesis, and its final contributions. First, Values studies have developed important but inconsistent traditions in philosophy, economics, psychology, sociology, anthropology, and geography (Boudon, 2001). In spite of this diverse scholarly attention, or perhaps because of it, the science of values is plagued by inconsistent definitions across disciplinary boundaries, the conflation of values with closely related but distinct concepts, and disagreement over how values originate, propagate, and operate. To meet these challenges in the context of this research, a well-established and robust definition of values, the Theory of Universal Values supported by research involving over 10,000 individuals was chosen (Sagiv et al., 2017). This scholarship, which emerged from the field of psychology provided the rich theoretical background to this work, and led to the adoption of values activation as a means to enhance online participatory environmental management.

11.2.2 Summary and Concluding Thoughts Related to Decision Support Systems and the Decision Sciences

A participatory decision-support system was designed to capture and leverage salient aspects of values to enhance the process of providing input on an environmental management issue. The impact of P2P-DSS was evaluated by analyzing user inputs generated using P2P-DSS, and with a post-task survey completed by study participants. Feedback from a formal decision-maker and fifteen participants indicate that the decision support system encouraged users to think about their own values while using P2P-DSS and assisted them in aligning their stated preferences with their values (Chapter 6). While the contributions from this thesis will benefit from future applications with larger study groups, developing and applying the theories that are foundational to the proposed approach has provided an opportunity to advance the study of values-based participatory decision support systems. Specifically, this study demonstrates a role for the theory of values activation in expanding the reach of values-based decision-making.

Next, this dissertation was influenced by studies in the Decision Sciences. Specifically, studies in facilitated values-based thinking in decision-making have documented measurable benefits for multiple participant decision-making. For example, the methodology Values-focused Thinking (VFT) has been studied in a range of real-world applications including military, government, environment and energy, and corporate decision contexts (Parnell et al., 2013). Among many observed benefits of values-based decision-making, VFT participants experience enhanced learning about their own perspectives and that of other people who held similar or diverging views (McDaniels, et al., 2001). Integrating VFT also supports participants in considering important trade-offs (Merrick & Garcia, 2004). Reid et al. (2014) found that basing a participatory process on values effectively engaged community members in climate change adaptation planning and Arvai, Gregory, & McDaniels (2001) report that VFT participants learned more about the decision being examined and felt they could make more informed decisions. In the same study, value-focused participants felt the process helped them to make values-congruent decisions (Arvai et al., 2001). Overall, the VFT approach results in more thoughtful participatory processes, better informed decisions, and helps to capture and integrate the values of more stakeholders. These findings resonate well with empirical evidence from the field of psychology which shows that values operate sub-consciously, but can influence decision-making and behavior when activated (Boer, 2017; Sagiv, Sverdlik, & Schwarz, 2011; Schwartz, 2017).

While acknowledging the ongoing contributions associated with multi-step decision structuring frameworks, such as Value-focused Thinking (Keeney, 1992), the Analytical Hierarchy Process (Saaty, 2008), and Fuzzy Cognitive Mapping (Giordano et al., 2010; Groumpos, 2010), this thesis argues that for some purposes, values-based decision-making can be prompted without requiring users to engage in unfamiliar decision structuring methodologies. This claim was developed with reference to the two theoretically rich and established areas of research, the Theory of Universal Values (Schwartz, 2017; Schwartz & Bilsky, 1990; Schwartz & Bilsky, 1987; Schwartz, 2012) and the theory of values activation (Grube et al., 1994; Hosack, 2007; Hosack & Paradice, 2014; Rokeach, 1968; Rokeach, 1975; Verplanken & Holland, 2002). Further studies into applied values activation for environmental decision-making may lead to a range of new participatory techniques and approaches.

11.2.3 Summary and Concluding Thoughts Related to Linking Values and Participation

Removing barriers to participation in facilitated values-based approaches is challenging. Values are typically held subconsciously and articulating, understanding, and using them purposefully for decision-making is effortful. The demands of values-based thinking introduce the potential for added stress and cognitive fatigue (Arvai et al., 2001; Keeney, 1994). A subsequent reliance on workshops with skilled facilitators has limited the potential reach of values-based approaches in practice (Bessette et al., 2016; Keller, Kirkwood, & Jones, 2010). This indicates that a gap exists between the known benefits of focusing on values for decision-making and the support available for engaging in values-based public participation. In an effort to facilitate the collection and integration of perspectives from more people, decision support systems such as an online decision-aiding framework developed and tested by Bessette & Arvai (2018) and Bessette et al. (2016), and a spatial decision support system for collecting public preferences about wind farm locations have been developed (Gorsevski et al., 2013).

This area of research needs to tackle questions about whether or not the benefits of values-based decision-making are manifested only with support from skilled facilitators using structured decision-aiding techniques, how effectively online techniques can retain those benefits, and what types of new benefits and trade-offs emerge when engaging in online values-based thinking. So far, these studies indicate that some benefits of values-based thinking are maintained even when using online approaches but the picture is far from complete. For example, Bessette et al. (2016) found that participants reported high and moderate satisfaction with the accuracy and values-congruency of their choices when using an online decision aide. However, the authors acknowledged that computerization likely added cognitive costs and stress to the process (Bessette et al., 2016). This dissertation has contributed theoretical and methodological insights to this emerging area of study by addressing two research questions (1) "How can one operationalize values-based decision-making for enhancing environmental management?" and (2) "What are some of the contributions that operationalizing values-based decision support can offer participatory decision-making".

11.2.4 Summary and Concluding Thoughts Related to Research Question 1

In addressing research question 1, this thesis pursued the specific objective to "Design, develop, and test a software program operationalizing values to facilitate values-based decision-making during the evaluation of decision alternatives". First, applying the theory of values activation was proposed as a mechanism for operationalizing values-based decision-making because activating values occurs routinely in peoples' lives, with and without their awareness (Boer, 2017; Schwartz, 2017), thus it can be achieved with or without facilitated procedures. By integrating values activation into an online survey this research worked towards expanding the impact of values-based decision-making in connecting formal decision-makers with the public they represent. This method was then tested with reference to a real-world environmental management issue, thereby benefiting from the perspectives of potential end users and integrating constraints and parameters identified by professionals and individuals in environmental decision-making.

This thesis has evaluated the impact of P2P-DSS from the user perspective. For example, responding to a post-task survey, the majority of participants indicated that they were satisfied with the preference input they were able to provide using P2P-DSS. The majority of participants felt that the process had influenced their preferences, while fewer participants actually changed the rankings they submitted while using the system. These criteria are important because they are used to evaluate the benefits of values-based decision-making and are thought to lead to more thoughtful, better informed, higher quality decisions during participatory processes (Arvai et al., 2001). Finally, may of the participants believed they had gained insights into the perspective of the model builder even when they did not share their perspective. Creating shared understandings, even under conditions of disagreement is a critical step in conflict management (Yousefi, Hipel, Hegazy, Witmer, & Gray, 2007).

11.2.5 Summary and Concluding Thoughts Related to Research Question 2

In examining research question 2, this project aimed to identify specific and practical contributions that values-based decision support can make to participatory decision-making. This generated links between the decision sciences literature and participatory modeling scholarship. This question was pursued with two objectives in mind.

The first objective was to "identify and illustrate techniques and protocols to generate a collective preference ranking from individual preference rankings collected using the values-based approach". Policy and management decisions are not scoped at the individual scale, but involve many people in diverse ways who may be organized into dynamic or stable groups. An array of voting rules have thus been developed to aggregate individual preferences that are useful for environmental managers, each with corresponding benefits and flaws (Burgman et al., 2014). Thus, it was important to develop and demonstrate a protocol to make the individual P2P-DSS data useful in group decision-making to lay the foundation for future applications in case studies. Accordingly, Chapter 8 demonstrated a method to use the survey data collected to create individual and group preferences rankings to inform decision-making.

The second research objective that addressed research question 2 was to "evaluate the values-based data collected and examine potential contributions of the dataset to understand the role of values in environmental conflicts". Chapter 10 identifies a new dataset that emerged from this research and presents its capacity to make underlying values conflicts explicit to inform strategic and pro-active conflict management.

Because this work is interdisciplinary in nature each manuscript included in this thesis was preceded by a short chapter. This provided an opportunity to directly address any nuances or complications that arose during the course of this study in terms of disciplinary conventions and terminology. While these chapters aim to add clarity to the organization of this thesis, the remainder of the conclusion will focus on the thesis contributions made in the thesis manuscripts. Thus, the following section will discuss the specific contributions made by each of the chapters consisting of manuscripts included in this thesis.

11.3 Discussion of Chapter Contributions for Each Chapter Comprised of a Submitted or Published Manuscript

Chapter 4 makes contributions to the fields of Conflict Resolution and Environmental Management, as well as specific contributions to this thesis.

First Chapter 4 built upon previous studies applying the Graph Model for Conflict Resolution (GMCR) to a brownfield management conflict in Elmira, Ontario. This conflict was previously modeled by Hipel et al. (1993). This earlier model which focused on the conflict during negotiations over control order issued to Uniroyal Ltd. by the Provincial Ministry of Environment was subsequently used for illustrative purposes as the GMCR approach was developed and expanded (Bashar, Kilgour, & Hipel, 2012, 2014; Fang et al., 1993; Hipel, Kilgour, Fang, & Peng, 1999; Inohara & Hipel, 2008a, 2008b; Kilgour, Hipel, Peng, & Fang, 2001; Xu et al., 2018). The manuscript included as Chapter 4 updated the earlier model to integrate aspects of the conflict evolution that occurred between 1989 and 2016. This contribution will provide a more temporally relevant model for future studies in GMCR, and accounts for developments of this environmental management issue.

The primary contributions of Chapter 4 to this thesis were methodological. The work that culminated in this publication was conducted in parallel to the development of the P2P-DSS system and informed the design choices implemented into the software program. As such, many of the design choices are best understood after gaining familiarity with the methods described in the paper. Specifically, this manuscript provides an example of established methods for modeling human dimensions in decision-making. While GMCR takes a game theoretic approach, integrating solution concepts (Fang et al., 1993; Liping Fang, Hipel, & Kilgour, 1989; Xu et al., 2018), the P2P-DSS approach draws upon psychology, integrating the theory of values activation (Grube et al., 1994; Roccas & Sagiv, 2017; Rokeach, 1968; Schwartz & Bilsky, 1987; Verplanken & Holland, 2002). In spite of this difference, Chapter 4 provided an illustration of the types of insights and analysis that are available when implicit aspects of human decision-making are made explicit through modeling.

Next, Chapter 4 described and demonstrated the use of preference ranking to include preferences in an interactive modeling environment. By demonstrating the technique of preferences ranking for decision modeling, the research informed the design of the P2P-DSS interface. The preference ranking technique used in Chapter 4 was subsequently adapted for use in P2P-DSS based in part on its effectiveness in the GMCR approach. Thus, the manuscript in Chapter 4 contributed to this thesis by illustrating one way to operationalize preferences for enhancing environmental management using preference ranking and user-friendly problem structuring techniques in an interactive decision support system. Subsequent chapters in this thesis then expanded on this work by studying opportunities to capture and operationalize the values that are foundational to preferences.

In **Chapter 6** the application of a theory from personality and social psychology, values activation (Grube et al., 1994; Rokeach, 1968; Rokeach, 1975), was proposed as a theoretical framework to operationalize values-based decision-making for enhancing environmental management. While there exists a strong literature connecting values activation with choices and behaviors (Boer, 2017; Feather, 1995; Grube et al., 1994; Rokeach, 1968; Schwartz, 2017; Stern & Dietz, 1994), there is little published work studying values activation using software generated feedback, such as the mirror element used in P2P-DSS; For exceptions see Hosack, (2007) Hosack & Paradice (2014) and Rokeach (1975). In addition, no research was found that applied values activation using software feedback to the development of values-based decision support. This is an important gap because activating values is possible without requiring users to learn unfamiliar methodologies, and this may provide the basis for a suite of techniques that make values-based decision-making more accessible in some contexts.

Chapter 6 then addressed objective 1, to “Design, develop, and test a software program operationalizing values to facilitate values-based decision-making during the evaluation of decision alternatives” This objective was one way to examine Research Question 1 because it provided the context for evaluating the potential impacts of using values activation to enhance environmental management decision-making.

The decision support system, P2P-DSS, adapted the preferences ranking technique used in the Graph Model for Conflict Resolution (Fang et al., 1993; Xu et al., 2018) and employed in Chapter 4 of this dissertation. The adapted preferences ranking approach was then expanded by combining it with interactive visual feedback related to the values that are foundational to preferences. In so doing, the theory of values activation was tested for the first time in a prototype participatory decision support system. P2P-DSS was then tested and evaluated with a participant group who used the system to provide input and completed a post-task survey. While the technique used in this research can be changed and improved upon in future studies, the approach presented here is intended as a demonstration of concept, and is a tool enabling users to delve into the connections between their values and preferences while considering their preferred decision outcomes.

Chapter 8 addressed the second research objective, “Identify and illustrate techniques and protocols to generate a collective preference ranking from individual preference rankings collected using the values-based approach”. This is an important objective because environmental conditions have local and non-local impacts and thus their management is characterized by the need to take into account the competing and differing needs of multiple people and groups (Pahl-Wostl, Palmer, & Richards, 2013; Reed, 2008; UNDESA, 2014). Thus, one challenge to operationalizing values-based decision support such that it can contribute to participatory processes is that the information generated using a computer facilitated survey such as P2P-DSS is collected at the individual scale.

Many methods exist to aggregate individual rankings into collective utility frameworks, each coming with their own advantages and trade-offs. Chapter 8 reviewed many of these approaches and demonstrated that the Modified Borda Count (MBC) (de Borda, 1781; Emerson, 2013) could be readily applied to the P2P-DSS rankings. This contribution is important because it demonstrated the flexibility of the P2P-DSS approach, which can be combined with other existing analytical techniques such as the MBC. Moreover, operationalizing values for participatory decision-making means making values-based preferences useful and available to decision-makers. In policy and management contexts, individual preferences are not as useful as preferences that can be analyzed at multiple scales. Chapter 8 thus establishes a framework for generating collective values-based choice models using P2P-DSS. This, in turn, lays the groundwater for future research studying values and preferences in environmental applications using P2P-DSS.

Chapter 10 makes methodological and theoretical contributions to the field of Conflict Studies and to the second research question in this thesis. These contributions are achieved by pursuing the research objective to "evaluate the values-based data collected and examine potential contributions of the dataset to understanding the role of values in environmental conflicts", thereby proposing and demonstrating one way that making assumptions about values explicit through participatory modeling can contribute to greater understandings about the drivers of conflict. This is important because failing to take into account the competing interests and perspectives that give rise to conflict can lead to poor planning and impede the implementation of projects and proposals (Hostmann et al., 2005; Pahl-Wostl, 2002) Moreover, conflict often arises when people hold incompatible values frameworks causing them to differ in their perspectives on a decision or problem (Keeney, 1994).

Focusing on landscape studies, Greg Brown, Kangas, Juutinen, and Tolvanen, (2017) differentiate between interpersonal conflicts and those that are driven by values. This is an important distinction because empirical studies have shown that certain types of

conflicts require different management approaches, as those approaches that may mitigate non-values conflicts can escalate conflict when deeply held values are activated (Ginges et al., 2007; Hanselmann & Tanner, 2008). Values-focused thinking (VFT) approaches address values conflicts by implementing problem structuring techniques, and public participation geographic information systems (PPGIS) have used participatory mapping to study values conflicts. These techniques continue to make considerable contributions to the understanding of values conflicts that have inspired this work, however they both require users to learn formal techniques that may be unfamiliar (Brown & Brabyn, 2012; Brown & Hausner, 2017; Brown & Raymond, 2014; Munro et al., 2017; Parnell et al., 2013).

The methodological contribution in Chapter 10 is in developing and testing a technique to collect information about the values assumptions of P2P-DSS users using the interactive 'protest' element. This is not intended to replace previous approaches that utilize problem structuring or participatory mapping, but to contribute to another suite of tools for contexts where the impact of VFT and PPGIS are limited. For example, while this study was conducted in a university setting, future studies will be conducted using P2P-DSS as an online survey. The theoretical contribution made by Chapter 10 is the proposed relationship between protested values and options and conflict potential which is explained and illustrated in this thesis.

11.4 Important Considerations and Future Research Directions

11.4.1 The Influence of Power Dynamics

One area of study that is relevant to the dissertation topic, but did not receive full attention is that of accounting for power dynamics that arise during participatory processes. Addressing power dynamics was not a primary goal of the thesis, but it must always be a consideration in studies of environmental participation. While providing public input online can reduce the impact of power dynamics by reducing the role of intimidation, providing opportunities for confidentiality and anonymity, and allowing individuals to provide input from comfortable and private spaces, power dynamics nonetheless exist in all participatory processes (Barnaud et al., 2006). In this research, the primary approach to managing power relations has been confidentiality. The participants were not informed of the level of expertise or the role of the formal decision-maker nor were participant inputs associated with their identity. The interactive tools provided a confidential method to providing preferences. There exists a need, however, to further examine the role of power dynamics in participation techniques when they are moved into online settings.

11.4.2 Potential Impacts of the Modeling Approach

The design of any modeling platform creates boundaries around the information that will be included, necessarily highlighting and excluding aspects of the system being modeled. Important trade-offs are made, for example in balancing representational completeness of the model, for example the level of detail and the number of factors that are included, as opposed to the transparency and simplicity of the model. While the former may increase model accuracy, the latter is associated with increased accessibility, a key goal in the development of participatory tools (Vezér, Bakker, Keller, & Tuana, 2018). That said, simplicity is not always associated with a lack of accuracy, as simple models can be appropriately complete for aiding and informing decision-making (Vezér et al., 2018). Decision-makers implicitly or explicitly make trade-offs in real-world contexts, and making those trade-offs explicit is associated with better, more informed decision-making (Garner, Reed, & Keller, 2016). Capturing and communicating trade-offs in an interactive model is the goal of P2P-DSS, and this thesis argues that by operationalizing values activation P2P-DSS illustrates one way to balance the need for simplicity of use and model completeness for the task of making values trade-offs explicit.

Model calibration in P2P-DSS reflects the subjective perceptions of the decision-maker who is seeking public input. The subjective nature of the model is an intended feature of the system that reflects the reality that decision contexts are subjectively perceived and understood by each individual. It is expected that a formal decision-maker (F-DM) could provide different inputs calibrating a given model based on any number of criteria including mood, recent experiences, and time of day. It is also possible that another F-DM would calibrate a different model.

This subjectivity could undermine the perceived legitimacy of the system from the perspective of the public participants. In this research, we did not reduce this risk, but managed it by way of transparency. The F-DM was informed that the model parameters provided an interactive space rather than an objective truth, and that participants would be given the opportunity to challenge the model assumptions. Similarly, participants were informed that the model was based on a subjective evaluation provided by a confidential informant with a professional connection to the issue. All participants were informed of the role that subjectivity played in achieving the goals of using P2P-DSS, which are outlined in Chapters 6.

Subjectivity in the model building process also creates research opportunities. Like any model building activity, P2P-DSS captures salient aspects of the system at a moment in time. As with fuzzy cognitive maps (Khan & Quaddus, 2004) future studies with P2P-DSS can be conducted comparing multiple models created by different decision-makers, or by tracing the evolution of a single decision-makers' model over time, providing insights into how decision-makers view decisions dynamically. Modeling human dimensions of decision-making is a robust area of study in conflict studies and the decision sciences. Future work with P2P-DSS will make further contributions to this area of study with a focus on bridging insights from psychology and decision sciences to enhance and understand environmental decision-making.

11.4.3 Challenges and Considerations in the Study of Values

One difficulty associated with values research emerges from the positive associations that people tend to have about all values (Roccas et al., 2017; Schwartz, 2017; Schwartz & Bilsky, 1987). While most people would rate all values as being important, determining a values framework requires people to report on the relative importance of different values (Roccas et al., 2017). In the Schwartz Value Survey, for example, this is accomplished by instructing people to make an effort to distinguish between more and less important values (Roccas et al., 2017). The implementation algorithms used in the mirror feature of P2P-DSS automate this task and provide feedback in the form of a visual values framework.

In circumstances where a small number of values are identified as relevant to a particular option, priming may influence the participant input. This is because people typically view all values as important (Roccas et al., 2017; Schwartz, 2017), thus a specific value may need to be evaluated in comparison to all other values otherwise the values that are highlighted may become more consciously available subsequently priming participants to report that the more available values are more important than they would be in the absence of priming (Roccas et al., 2017). The impact of priming has been studied in terms of its capacity to induce changes in values and emergent behavior (Maio, Pakizeh, Cheung, & Rees, 2009; Verplanken & Holland, 2002). Future research using P2P-DSS should consider how the visual representation of values frameworks may prime users in their responses. For example, one option to study the potential impact of priming when using P2P-DSS could be an experimental study comparing the methodology employed in this study with a sample in which participants are confronted with a comprehensive (including a full set of values) equally distributed mirror rather than a presumed personal framework.

Studies that involve personal values are challenging because personal values are subjective and often sub-consciously held. Because of the subjective qualities of values, most techniques commonly used in values research rely on self-reporting of values (Roccas, Sagiv, & Navon, 2017). There are, however, many ways to deliver self-reporting techniques. For example, early surveys gave participants tasks such as assigning importance weights to highly abstract values, with no context or comparison values provided. This was found to be difficult for participants leading to approaches that integrated concrete examples to facilitate the elicitation of values information (Roccas et al., 2017). For example, the Portrait Values Questionnaire provides descriptions of hypothetical individuals with unique values frameworks which participants then compare to their own self-perceived values (Schwartz et al., 2001). Studies to evaluate under which conditions more abstract or more concrete approaches are appropriate are ongoing (Roccas et al., 2017). As the P2P-DSS approach matures, researchers will need to follow this scholarship closely as it may provide guidance in terms of adapting the pre-defined values integrated into the model to match the goals of individual studies.

A second challenge to integrating values into this study has been the adoption of the Theory of Universal Values in an environmental application. The ten values identified in the Theory of Universal Values (Schwartz & Bilsky, 1987; Schwartz, 1994) are not all labelled in ways that easily connect with the specific Jigs Hollow controversy. For example, the value '*Security*', which is associated with safety and stability of society and of the self (Schwartz, 1994, 2012), may be readily associated with a desire to protect society and self from economic or environmental consequences of below-water extraction. However, it is not as clear how the value *"Hedonism",* associated with pleasure (Schwartz, 1994, 2012) relates to assessment over an aggregate mining application.

While connections can be proposed between hedonism and the application, for example, the degree to which an individual anticipates enjoying recreational activities on a naturalized lake, the labels and definitions of some values nonetheless needed to be adapted to facilitate model creation and subsequent participant interactions. For example, the value "*hedonism*" was replaced with a more-simple and commonly used label "*enjoyment*". Thus, as was discussed in greater detail in Chapter 6 of this thesis, changes to the original set of values as defined by Schwartz (1994) were informed in part by a review of environmental literature related to environmental values and ethics (Dietz et al., 2005; Euzen & Morehouse, 2011; Hillier, 1999; Stern & Dietz, 1994; Vanderwarker, 2012) and in part through conversation with the formal decision-maker volunteering for this study.

Where the values included in the model were re-written to improve ease of use and clarity, they were also defined to conceptually represent values related to the Schwartz Theory of Universal Values based on similarities between values definitions. This approach to defining and integrating values was chosen to capture the perspective of the formal decision-maker perspective of the F-DM, although it does involve a trade-off in conceptual consistency with the original TUV. It is therefore important to clarify the theoretical basis for this choice and to present an alternative approach that may be employed in studies prioritizing conceptual consistency with broader literature on personal values.

The main thrust of the Theory of Universal Values (Schwartz & Bilsky, 1987; Schwartz, 1994) is the existence of the motivational continuum on which can be a range of values, from which researchers can draw the number of values relevant to their study (Schwartz, 2014). For example, some researchers have focused studies on the 4 higher order values of Openness to Change, Self-Transcendence, Self-Enhancement, and Conservation, into which the ten TUV values are organized, while others focused on the ten values that fit within those four higher order values (Schwartz, 1992; Schwartz et al., 2012). Alternatively, more narrowly defined values can be identified and placed on the TUV continuum, adding refinement to the ten universal values (Schwartz et al., 2012). For example, Schwartz et al. (2012) discriminated between two types of security values, personal security and societal security and then used empirical studies to demonstrate that this differentiation increases the predictive capabilities of the TUV model. The Refined Theory of Values (Schwartz et al. 2012) expands on the original TUV, but does not contradict the original model or its content, demonstrating that combining or differentiating adjacent values can be a useful and compatible approach for topic-specific research. This provides opportunities to tailor the number of values and the broadness of the defined values used in a study, to match the research conditions and goals (Schwartz et al. 2012).

The refined theory of values lends empirical support to the idea the TUV values can be partitioned towards broader or more specific values that may be useful in different research contexts. For future studies, it may be useful to integrate the narrowly defined values that have been confirmed by Schwartz et al. (2012) rather than developing decision-specific values. However, doing so may result in greater model complexity and will not capture the F-DM perspective at the stage of defining values. Currently, flexibility of use has been maintained to facilitate alternative treatments of values, by making the editing function for defining values accessible and intuitive to use. Future studies will be needed to evaluate the costs and benefits associated with these two approaches.

Finally, because values are almost always considered to be positive, making a specific value more consciously available may cause participants may to remember that it is important to them, and thus to more effectively engage it in their evaluation (Roccas, 2003). This potential for priming has been raised in relation to the development of tools for reporting and measuring values priorities and has consequences for how values activation can impact decision-making and behavior (Roccas, Sagiv, & Navon, 2017). This has made priming a valuable tool to study and demonstrate the relationship between values activation and behavioural outcomes (Roccas et al., 2017; Verplanken & Holland, 2002). However, priming can also operate as an unintentional outcome of values research, for example, when only a small set of values are under study (Roccas et al., 2017). One approach to mitigate the impact of priming has been to include the full spectrum of values in measurement techniques even when one or a smaller subset of values are the study focus.

This complication may arise in use of P2P-DSS if a model is developed that heavily weights towards a small set of values. To manage the potential for values priming when using P2P-DSS, descriptions for the full suite of modeled values are visually presented and defined on the interactive web page, even in cases where the calibrated model only includes a small set of the values as represented on the mirror. This design choice is intended to moderate the influence of priming that could result from a potentially unbalanced values framework depicted in the mirror. While this design choice is supported by the values research cited above, it was not directly examined in the course of this study. A future study is recommended to test aspects of the P2P-DSS interface for instances of priming, and examining how differently calibrated models may influence participant responses.

The next recommended step to begin such studies will be to provide the means for using P2P-DSS in experimental conditions with control groups that can isolate variables in the software program. There are two primary ways to approach such experimental studies. First, between-subject studies (Leroy, 2011) can be launched in which independent variables, the potentially priming elements, can be manipulated for one sub-set of participants, while the other sub-set of participants will use the standard P2P-DSS format. Alternatively, within-subject studies (Leroy, 2011) can be conducted in which each participant uses the P2P-DSS system more than once with the independent variables adjusted and participant behavior measured. The former approach will require the development of multiple P2P-DSS interfaces with specific variables changed and a large pool of participants, but does reduce participant fatigue as compared to within-subject studies. The latter approach similarly requires P2P-DSS interfaces or modules that manipulate the independent variables and is more demanding of individual participants. This approach also requires the establishment of base-line proficiency such that changes in participant use can be traced to the variables under study rather than proficiency with the novel P2P-DSS interface. This second approach is proposed for a future research project that will begin with the development of instructional videos and base-line proficiency evaluation. Within-subject design is being pursued because of its capacity to control for variables that are not of interest to the study, known as nuisance variables (Leroy 2011). In this study, for example, proficiency with computers, interest in the decision being modeled, life-experience, and pre-existing values frameworks are all variables that may influence participant interactions in a controlled study of the effects of priming when using P2P-DSS.

11.4.4 Evaluating Online Participation in a Research Setting

In testing P2P-DSS, hosting participant meetings in a controlled setting instead of launching P2P-DSS online involved many trade-offs. The choice to invite participants to the university computer laboratory was made because having a facilitator present provided an opportunity to observe user interactions and identify priorities for design improvements. As such, this work reports on the experiences from a small participant group. Nevertheless, interpretations of the preference rankings and value-protests provided in Chapters 8 and 10 illustrate the types of data that can be generated using the P2P-DSS approach to values-based participation. Future research in which P2P-DSS is used to collect perspectives on environmental applications entirely online, and with larger participant groups will be needed to further examine the outcomes detailed in this study.

The first step towards this goal will be evaluating the likelihood of adoption of P2P-DSS by a group of decision-makers in governmental and regulatory roles. This is the next logical step because integrating end users is a best practice in decision support development in order to reduce the tendency for researchers to develop software systems that are abandoned when the research project is complete (Mysiak et al., 2008). Moreover, recruiting public participants for larger studies can be challenging. Building relationships with formal decision-makers who have a long-term commitment to a specific decision will be a critical first step in identifying and reaching out to stakeholders.

11.4.5 Study Limitations in Terms of Participation

In conducting this as pilot study within the constraints of the PhD program the number of formal decision-makers and public participants involved leaves some questions unresolved in terms of legitimacy of the models created and confidence in participant responses. First, this study relied on 15 participants, ten of which identified as students. While the study did not aim to be a comprehensive case study, but a proof of concept and setting the stage for future applications, this number of participants limits confidence that the responses collected are representative of what could be collected in a large case study. That said, in future studies with larger groups of participants there is reason to expect that recruitment for online polling approaches will continue to elicit responses from a skewed population sample. Moreover, it is possible that such a bias is close to representing the likely end-users of online participatory tools. For example, a study of participatory budgeting in Brazil found that university educated males under 30 years old with daily internet habits are more likely to vote online than other demographics (Mellon, Peixoto, & Sjoberg, 2017). Nonetheless, online voting still seems to capture a group of less-represented perspectives, Mellon et al. (2017) also found that 68.7 percent of online voters in their study would not have voted if the online option had not been available. Researchers in e-participation should give considerable thought to when their studies demand representativeness at a geographical or social scale, or within subsets of likely early or resistant adopters of *e*-government.

Moreover, in this study, one decision-maker was used to create the decision model and provide feedback related to the P2P-DSS program. This limits the insights gained regarding models built by decision-makers and raises specific questions about how the study may have been different in terms of the model content and the feedback provided on system use with a more diverse group of decision-makers. These questions can have implications for perceptions of the legitimacy of the model contents. The next logical step in studying the P2P-DSS approach will be to add clarity to such questions with an in-depth study on decision-maker models. Specifically, I propose to conduct a study in which a set of decision-makers independently create models along a single decision theme. These models can then be compared to evaluate degrees of similarity and difference within and between decision-maker sub-groups. This proposed study is outlined in further details in Section 11.5 'Future Research'.

11.4.6 Study Limitations in Terms of Scope

Being limited to research questions on how values could be activated using online decision support and how such an approach could benefit participatory environmental management, this study did not evaluate how the information generated using the P2P-DSS approach could be used by decision-makers. However, as this work lays the groundwork for future research into the use of the P2P-DSS approach in decision-making, it is worth adding some clarity as to how the values frameworks, preference rankings, and protests data could feed into a decision-making process.

The anticipated decision-making role of values frameworks generated using P2P-DSS as presented in this thesis is restricted to enhancing the process of providing input. The values frameworks are used as a deliberative tool, to enhance focus on personal values rather than on alternatives or options. This goal is informed by research indicating that focusing on values as opposed to options results in greater creativity and satisfaction in decision-making (Keeney 1992).

For formal decision-makers, the values frameworks serve to activate values-based thinking and to create a record of the decision-maker perceptions that can then be shared with the public using P2P-DSS. For participants providing input on a focal issue, the values frameworks serve to activate values-based thinking, to present a model of the decision-maker (model builder) perceptions and provide guidance in generating values-congruent preference rankings. Thus, in contexts similar to the Jigs Hollow example that illustrated P2P-DSS in this thesis, the values frameworks are not expected to provide a source of independent data to aide decision-makers. However, it is worth speculating future uses for the values frameworks in decision-making contexts. For example, in planning contexts, groups of decision-makers may wish to achieve, or be responsible for attaining stated strategic values. In these cases, the values-frameworks could be set to an ideal values framework and used to guide discussions and test values-congruency of strategic plans.

The preference rankings are the primary data that is anticipated to be used by decision-makers as a decision-aide. This dataset is not qualitatively different from other types of convenience voting methods that are delivered online, and a framework for aggregating the preferences for informing group decision-making is provided in Chapter 8 of this thesis. As with all convenience voting methods, whether they are applied to electoral or information gathering pursuits, the goal is to reduce the cost or effort required to provide input, for some citizens, while maintaining any existing benefits in terms of influence over the outcome of that vote (Mellon et al 2017). How a decision-maker uses the collected input will be context specific, as P2P-DSS is flexible to facilitate integration into participatory processes ranging from information gathering to consultation and direct democracy.

The potential role of protest votes collected by P2P-DSS is outlined in detail in Chapter 10. While this dataset is most suited for conflict prediction, it also provides insights to inform communication strategies. Altogether, P2P-DSS is not a stand-alone system and its use will be contextual, impacted by the motivations and constraints framing the broader decision context.

11.5 Future Research

In a future study, Decision-makers and regulators will be invited to learn about P2P-DSS using educational material developed for that purpose, and to complete a semi-structured interview in-person, by telephone or online. This study will focus on determining the willingness of the formal decision-makers to use P2P-DSS as part of a future participatory processes. A Strengths Weaknesses Opportunities and Threats (SWOT) analysis will then be used to evaluate the P2P-DSS approach in terms of its ease of use, perceptions of its usefulness, stated willingness to invest in its use, and factors that influence whether or not decision-makers are interested in using P2P-DSS for an ongoing case study. This information is important because it can contribute to scholarship on decision support systems best practices in participatory settings, inform priorities from a user perspective, and identify further refinements that may improve the usability and relevance of P2P-DSS for decision-makers.

A case study using P2P-DSS entirely online will then be conducted to collect public input related to the beneficial use of waste as a resource, including potable waste water recycling and agricultural biosolids applications in several locations. This is an ideal topic because evaluation of recycled waste materials for beneficial purposes involves the subjective evaluation of risk and benefit trade-offs, is influenced by unconscious psychological motivators, and is a compelling social issue that is particularly sensitive to public perception (Hurlimann & Dolnicar, 2010; Price, Fielding, & Leviston, 2012; Robinson, Robinson, Raup, & Markum, 2012). All of these issues are well studied in the personality and social values literature, and form an important area of interest in values-based scholarship (Arvai et al., 2001; Huang, Keisler, & Linkov, 2011; Parnell et al., 2013). This work will be poised to make considerable contributions to scholarship in risk analysis, values-based decision-making, and technology adoption in environmental applications.

Looking ahead, P2P-DSS is well-suited to serve as a module in larger participatory and analytical processes. The development of a modular version of the mirror which could be embedded opportunistically into online surveys was not a focus of this thesis, but it could greatly expand the reach of values-activation based research. This step could leverage an advantage of decision support system use that often goes unrecognized, namely, that by interacting with a DSS users can learn the logic rules or methodology that it is designed to facilitate. This process has been raised by Newman, Lynch, & Plummer (2000) and Mysiak et al. (2005) as cause for DSS abandonment (as the user no longer requires the system) that complicates the evaluation of DSS success. This raises questions about the potential impact of making a value-focused feature available in online surveys. Specifically, to what degree, if any, will individuals internalize the process of explicitly linking preferences to values that is embedded in P2P-DSS and will that have implications for their decision-making in other domains?

Such a study may make interesting connections with research into values change. While values are trans-situational and considered to be relatively stable across time (Roccas et al., 2017), changes to values have been noted in experimental conditions (Grube et al., 1994; Maio et al., 2009; Rokeach, 1975). Moreover, Bardi, Lee, Hofmann-Towfigh, and Soutar (2009) found that increasing the importance of specific values causes increases in the importance of closely related values and is accompanied by a decrease in the assessed importance of incongruent values. How long observed changes to values frameworks persist is, however, not clear. Nonetheless, this body of work raises important ethical and practical questions regarding the implications of highlighting specific values frameworks online in participatory processes. While such questions are beyond the scope of this dissertation, by testing the theory of values activation and developing a technique to operationalize it using a participatory modeling framework, this thesis has laid important groundwork that could contribute to their future study.

11.6 Summary of Concluding Chapter

In sum, this work first tests an approach to using the theory of values activation as a way to bridge the gap between the benefits of values-based decision-making and techniques for operationalizing values in a decision support system. Findings from this work then indicate that P2P-DSS encouraged users to engage in values-based decision-making and examined ways that the data generated using the values-centric interface can be aggregated into collective preferences. This research then contributed a new way to explore the roots of conflicts across and between groups. These contributions are important because environmental management issues involve value-laden judgments, thus the study of public participation in environmental contexts requires a robust understanding of how values frameworks impact decision-making. Moreover, supporting creative outcomes over conflict demands an understanding of how values operate in these complex issues. This research lays the foundations for a range of future studies, as described above, by working towards the advancement of theoretically rich techniques for focusing on values in decision-making.

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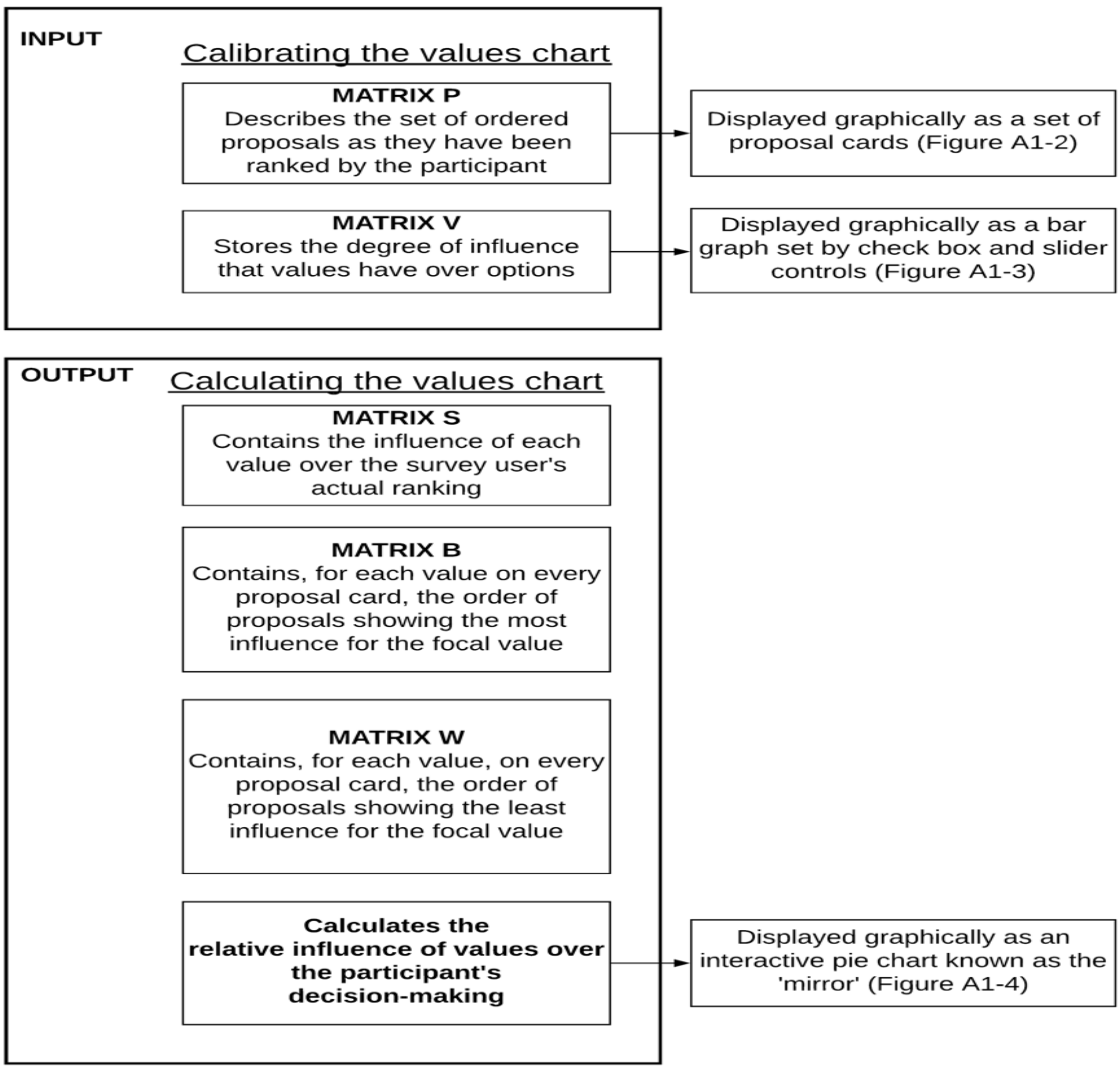
Appendix A

Representation of Algorithm Used to Generate the Values Mirror

The following algorithm describes the process followed by P2P-DSS in estimating and generating a visual representation of the values-framework that drives participant decision-making during the ranking of proposals. The process is conducted in several interrelated steps (Appendix A Figure 1).



Appendix A Figure 1 Outline of algorithmic steps followed by P2P-DSS to generate a values framework mirror.

Input (1)
Matrix P describes the set of ordered proposals as they have been ranked from most to least preferred, where ties are not permitted, by the participant. Within the matrix, each proposal includes the set of options that are associated with that proposal. This matrix is represented graphically on the P2P-DSS interface (Appendix A Figure 2).

In matrix P there is a row for each option (*m)* included in the P2P-DSS model. There is a column for each proposal (*n*) in the P2P-DSS model.

$$P=\begin{pmatrix} p_{11} & \cdots & p_{1np} \\ \vdots & \ddots & \vdots \\ p_{mp1} & \cdots & p_{mnp} \end{pmatrix}$$

Where
P = matrix containing the set of ranked proposals defined by the selected options.
m = number of options
n = number of proposals

Where values within the matrix are set by the following rules:
If Option *i* is not selected for Proposal *j* then
$P_{ij} = 0$
If Option *i* is selected for Proposal *j* then
$P_{ij} = 1$

In the Jigs Hollow expert model Matrix P is represented graphically, as illustrated in the following example prepared during the proposal ranking (Appendix A Figure 2). The checkmarks on Figure Appendix A-2 correspond to 1s on the Matrix depicted in Table Appendix A-2, while the options not chosen on a focal proposal correspond with the 0s.

Appendix A Figure 2 Visual representation of Matrix P as it appears on the P2P-DSS interface

Each proposal is represented graphically by a card, which corresponds to a column in Matrix P. Each option is described in text on the card and represented as a row in Matrix P.

Appendix A Table 1 Matrix P for the Jigs Hollow proposal ranking depicted in Appendix A Figure 2

0	0	0	0	0	0	0	1
0	0	0	0	0	1	1	0
0	0	0	0	1	1	0	0
0	0	0	1	0	0	0	0
0	1	0	0	0	0	0	0
1	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0

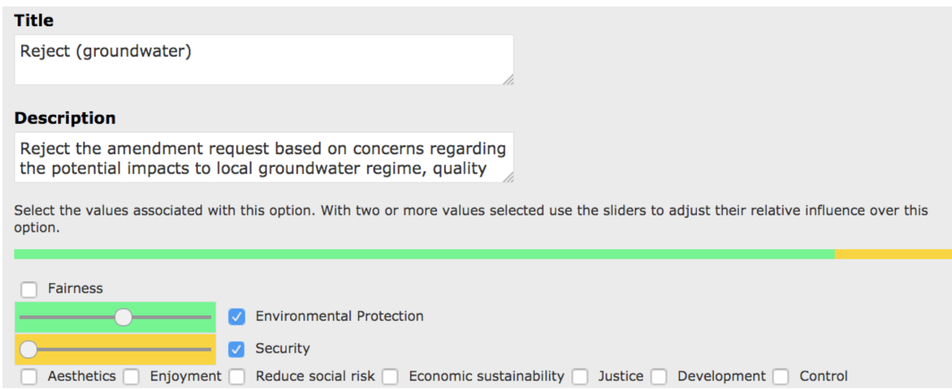
Matrix V

Matrix V stores the degree of influence values have over options. These data are input by the model author during default model calibration and by public participants when they choose to protest the default calibration. The relative influence of a focal value over an option can be set between 0 and 100% using slider controls. The values influence is depicted in matrix V_{mn}.

$$V = \begin{pmatrix} v_{11} & \cdots & v_{1nv} \\ \vdots & \ddots & \vdots \\ v_{m1v} & \cdots & v_{mnv} \end{pmatrix}$$

Where
v = the influence of a focal value over a specified option
m = number of values
n = number of options

Each column of matrix 2 is represented graphically on the P2P-DSS interface as a bar graph and set by check box and slider controls (Appendix A Figure 3).



Appendix A Figure 3 Visual representation of Matrix V as it appears on the P2P-DSS interface

Appendix A Table 2 Matrix V for the Jigs Hollow case study, showing the values influence for the Reject (groundwater) option

…	…	…	…	0	…	…
…	…	…	…	80	…	…
…	…	…	…	20	…	…
…	…	…	…	0	…	…
…	…	…	…	0	…	…
…	…	…	…	0	…	…
…	…	…	…	0	…	…
…	…	…	…	0	…	…
…	…	…	…	0	…	…
…	…	…	…	0	…	…

Calculating the values chart

The 'mirror' illustrates the estimated influence that each value had over the participant's decision-making as they ranked the proposal cards. The relative distribution of values on the participant's mirror is determined using the data contained in matrices P and V.

During the calculation of the mirror, many intermediate matrices are used to store the relevant data to determine the participant's values framework while ranking the proposals. For each value, these intermediate matrices represent the participation submission (Matrix S), the ranking that represents the dominance of a value of the decision-makers rankings (Matrix B) and the ranking that represents the lack of influence of a value of the decision-ranking (Matrix W). Thus, Matrix S represents the ranking submitted by the participant. Matrices B the ranking that would be produced if a specific value was the dominant driver of the participant's ranking choices (best-case scenario), and Matrix W represents the instance in which a focal value had no positive influence over ranking choice (worst-case scenario). By combining these calculations, a relative influence for each value is determined. Each of these matrices are described in the following section.

Matrix S

First, the data in matrices P and V is used to calculate the influence of each value over the survey user's choice to place each proposal at a particular ranking location (to the left or to the right of the competing proposals) (S). The user is then free to modify V through the protest button or to modify P by changing their proposal rankings.

The columns stored in matrix S are also used to indicate the calculated relative influence of values associated with each proposal, which is depicted graphically on the P2P-DSS as a vertical bar graph along each proposal card (Appendix A Figure 2).

Matrix S

$$S = \begin{pmatrix} s_{11} & \cdots & s_{1ns} \\ \vdots & \ddots & \vdots \\ s_{m1s} & \cdots & s_{mns} \end{pmatrix}$$

$$S = V \times P$$

Where

s_{ij} = the influence of value *i* over proposal *j*

m = number of values
n = number of proposals

Matrix B
Matrix B is then calculated to represent the order of proposals showing the most influence for the focal value for each value on every card. This can be described as a 'best case scenario' for the specific value in that this is the order that would be chosen if the focal value was the only priority for the user.

$$B = \begin{pmatrix} b_{11} & \cdots & b_{1nb} \\ \vdots & \ddots & \vdots \\ b_{m1b} & \cdots & b_{mnb} \end{pmatrix}$$

Where
B = the best-case scenario for the influence of a focal value over a ranked proposal
m = number of values
n = number of proposals

All items in matrix B are derived from, and therefore identical to S, however, the columns can be sorted, but the rows are fixed.

Thus,
$b_{ij} = s_{ik}$
Where
$1 \leq i \leq mb$
$1 \leq j \leq n\text{b}$
$1 \leq k \leq n\text{b}$

The columns are sorted such that any proposal placed to the left has a higher numerical value than the value to its right. This can be described with the following equation:

$b_{ij} \geq \text{b}_{\text{ij+1}}$
Where
$1 \leq i \leq m\text{b}$
$1 \leq j \leq nb - 1$

Matrix W
Matrix W is then calculated to represent for each value on every card for the order of proposals showing the least influence for the focal value. This can be described as a 'worst

case scenario' for the specific value in that this is the order that would exist if prioritizing the focal value as least important was the only reason for the submitted ranking.

$$W = \begin{pmatrix} w_{11w} & \cdots & w_{1nw} \\ \vdots & \ddots & \vdots \\ w_{m1w} & \cdots & w_{mnw} \end{pmatrix}$$

Where
W = the worst-case scenario for the influence of a focal value over a ranked proposal
m = number of values
n = number of proposals

All items in matrix W are derived from, and therefore identical to S, however the sorting of the columns can change. This can be described as:

$$w_{ij} = s_{ik}$$

Where
$1 \leq i \leq m$w
$1 \leq j \leq n$w
$1 \leq k \leq nw$

The columns are sorted such that any proposal placed to the left has a higher numerical value than the value to its right. This can be described with the following equation:

$b_{ij} \leq b_{ij}+1$
Where
$1 \leq i \leq m$w
$1 \leq j \leq n-1$

Equation 1
Finally, the data stored in matrices S, B and W is used to determine an estimated influence of each social value over the decision-making that led to the final proposal ranking submitted by the survey user. This is represented by the matrix R_{1n}. The single relative number for each social value is then used to populate the values 'mirror'(Appendix A Figure 4).

$$R = (r_{11} \cdots r_{1n})$$

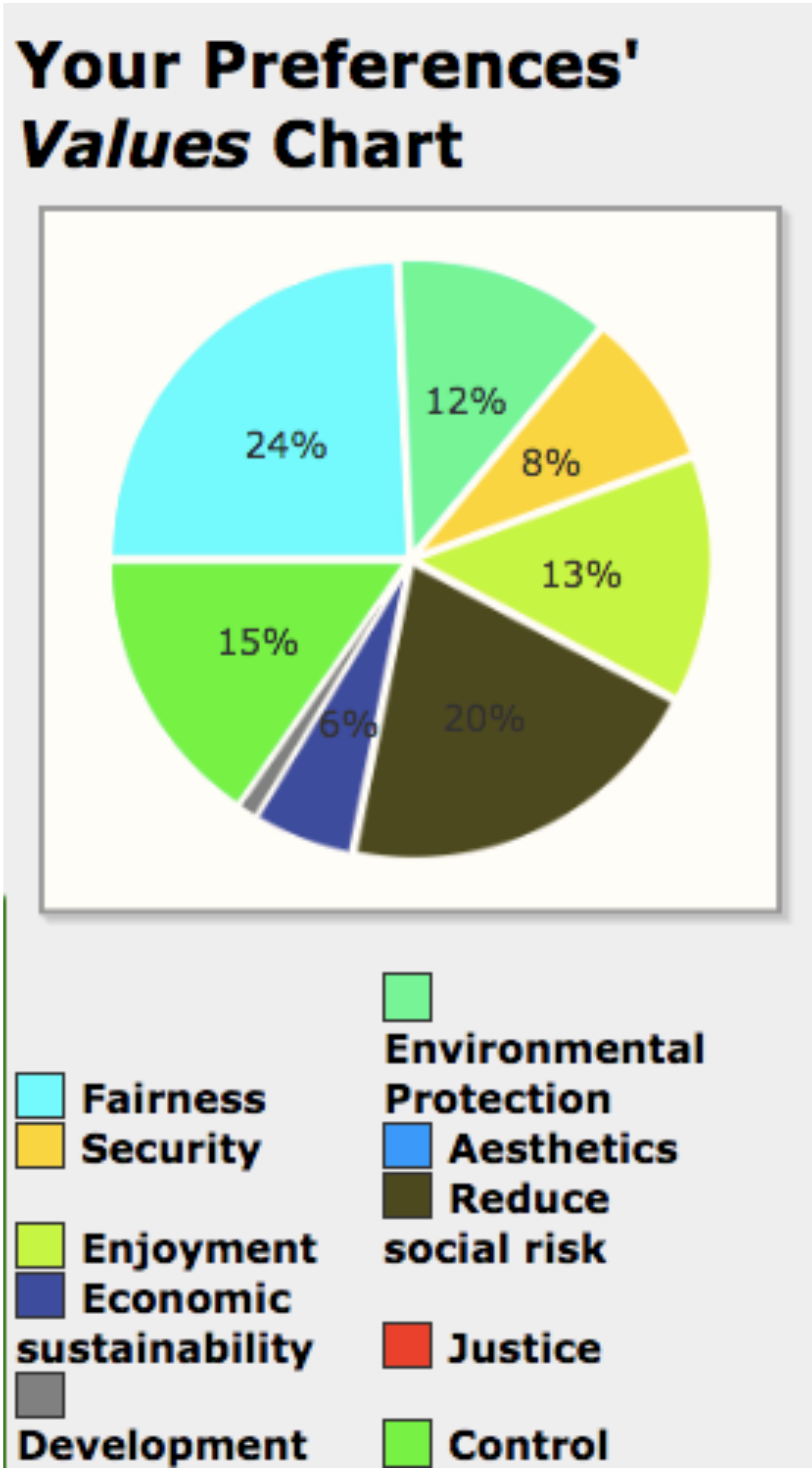
Where

n= number of values
r = relative influence of a value over the participants' decision-making during the ranking process.

The equation to derive R is described as:

$$r_{1j=} \sum_{k=1}^{m} \sum_{i=1}^{k} \frac{s_{ij} - w_{ij}}{b_{ij} - w_{ij}}$$

Where
m= the number of proposals
j = a focal value
k = indexer



Appendix A Figure 4 Output from equation R as it is displayed graphically on the P2P-DSS interfac

Appendix B

Post-task User Survey

Evaluation survey for public participations.

The following questions are designed to aid in the evaluation and improvement of the software program which you just used. You name will not be recorded in connection with this survey, however your gender and age are requested for research purposes. Please feel free to disregard any questions that you do not wish to answer. Complete responses will be of great value to the research results which you will have an opportunity to see at the completion of this study.

Part A Evaluation of the computer program.

1 How satisfied are you that you were able to express your preferred decision using this program? Please circle your response:

Dissatisfied	Not Satisfied	Neutral	Satisfied	Very Satisfied

2 What reason(s) do you have for your previous response? For example, what specific things did you like, or not like about the program? In what ways did the program help you to understand and express your preferences, or how did it fail to support your efforts?

3 If there was a future opportunity to use this type of program online to contribute to local decisions, how likely would you be to use it?

Absolutely not	Not likely	Not sure	Likely	Very Likely

3b Why or Why not?

4 What (if any) types of concerns could cause you to hesitate to use this service if it was available online?

5 Do you think that you could use this program without any help or guidance? Please circle your response:

Absolutely not "I felt the need for help throughout the program"	Probably not "I felt that the program was difficult and needed help several times"	Not sure "I did not always feel confident using the program"	Likely "I think I could figure it out on my own"	Very likely "I could use it without any help"

6 Can you describe any particular moments or actions that were confusing or frustrating?

Part B Perception of value of using the program.

7 Do you feel you know more about the decision presented today, after using this program?

8 Do you feel that your local managers and officials are likely to consider the responses you gave through this program when they are making a decision?

Absolutely Not	Not Likely	Not Sure	Likely	Very likely

8b Why or why not?

9 Did this program…

(9a) …Help you to state your own preferences:

Unhelpful	Somewhat Unhelpful	Neutral	Somewhat Helpful	Helpful

If you would like to expand on your response, please provide comments here:

(9b) …Encourage you to spend more effort considering your responses to the survey?

Strong No- A lot less effort “While using the program, I spent a lot less effort considering this question than I normally would”	Somewhat No - A little less effort “While using the program, I spent somewhat less effort considering this issue than I normally would”	Neutral “The program had no impact on how much effort I put into considering this issue.”	Somewhat “While using the program, I put a little more effort into considering this issue than I normally would.”	Helpful “While using the program, I put a lot more effort into considering this issue than I normally would”

(9c) …How did this activity impact your preferences:

Not at all	Not really	Neutral	A little	A lot

"After doing this activity, I am now more sure that my original preferences were the right ones."	"After doing this activity, my preference did not change"	"This activity had no impact on my preferences."	"After doing this activity, some of my preferences have changed"	"After doing this activity, many of my preferences were changed"

If you would like to expand on your response, please provide comments here:

(9d) …Help you to understand other people's preferences for proposals even if you don't agree with them:

Not at all	A little	A lot
"This did not help me to gain insight into other people's preferences"	"I gained some insights into why people prefer proposals that I do not support"	"I have a greater understanding as to why some proposals that I don't support may be preferred by other people"

Part C Getting to know you.

10 How often do you contribute to local decisions (through any method)?

Never	It depends	Less than once per year	Between 1-5 times per year	6 or more times per year

11 If/when you do contribute to local decisions how do you do it (you can choose more than one)?

Letters to newspapers	Direct letters to decision makers	Social media comments	Online surveys	Communit y meetings	Other* (please specify below)	Never N/A

12 Please indicate your gender:

Male	Female	Other	Prefer not to say

13 Please indicate your age range:

(18-25) (26-35) (36-45) (46-55) (56-65) (66-75) (76-85) (86-95) (over 95) (prefer not to say)

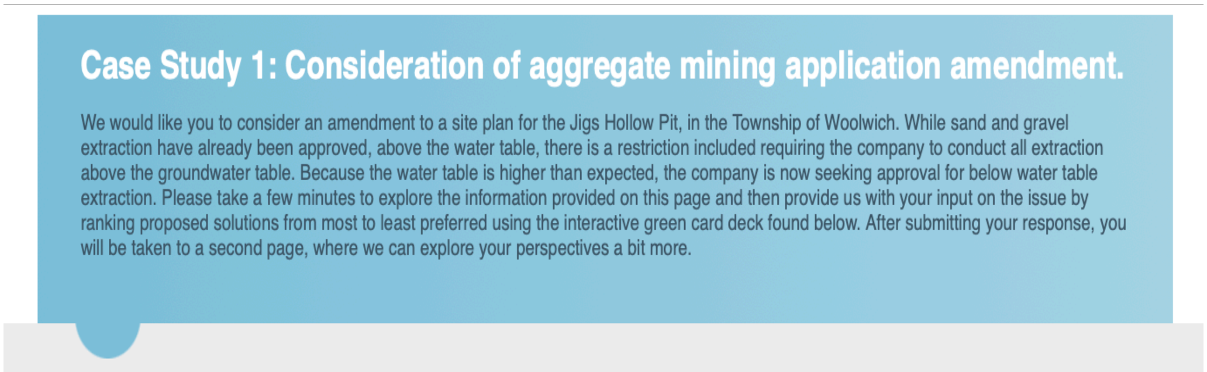
14 Please indicate your Postal Code or place of residence. This information will be used as part of our research. In particular, it will help us to examine how, or if, proximity to the impacts of the decision being studied impacts the responses of participants:

15 Would you like to be contacted for follow up information about this project, and for future opportunities to provide your input? If yes, please provide your email address.

16 Comments: please add any comments about this approach or exercise that you wish to share.

Appendix C

Preparatory Information Included on Page 1 of P2P-DSS



Appendix C Figure 1 First section of preparatory information provided on P2P-DSS. This content is included in-text below.

Content from Appendix C Figure 1 translated as text:

Case Study 1: Consideration of aggregate mining application amendment

We would like you to consider an amendment to a site plan for the Jigs Hollow Pit, in the Township of Woolwich. While sand and gravel extraction have already been approved, above the water table, there is a restriction included requiring the company to conduct all extraction above the groundwater table. Because the water table is higher than expected, the company is now seeking approval for below water table extraction. Please take a few minutes to explore the information provided on this page and then provide us with your input on the issue by ranking proposed solutions from most to least preferred using the interactive green card deck found below. After submitting your response, you will be taken to a second page, where we can explore your perspectives a bit more.

Gritty Details

While the company has already received approvals to extract sand and gravel from the site, an unexpected rise in the groundwater levels means that the current above-water extraction will not make the operation viable. Extraction below the water table will bring new positive and negative impacts to the operation and to the region. For one, the available sand and gravel available will be increased. However, different equipment will need to be employed to excavate in the water, some local citizens may be disturbed by this activity. It is nevertheless still anticipated that the absolute amounts extracted and the amount of traffic associated with the operation will not exceed the original approval. One major change is that the original above water extraction would have concluded with land restoration that returned the land to agricultural uses. Under this proposed change, the disturbances will be greater and that will not be possible. Plans have been made to create a lake at the extraction site, which could maintain new and diverse ecosystems and activities. There may be some increased risks to water quality in the immediate area (localities within 1km of the site), as the company is located adjacent to a river and the operations will have some groundwater impacts. These impacts are difficult to anticipate, and steps are taken to minimize them, however, they are important to consider.

Related Information

The following external resources
provide more information on this topic.

- Planning Summary Report
- Observerxtra.com

Appendix C Figure 2 Image from preparatory information section in P2P-DSS. This detailed information is placed just below the information provided in Appendix C Figure 1. A text version of this information is provided below.

Content from Appendix C Figure 2 translated as text:

Gritty Details:

While the company has already received approvals to extract sand and gravel from the site, an unexpected rise in the groundwater levels means that the current above-water extraction will not make the operation viable. Extraction below the water table will bring new positive and negative impacts to the operation and to the region. For one, the available sand and gravel available will be increased. However, different equipment will need to be employed to excavate in the water, some local citizens may be disturbed by this activity. It is nevertheless still anticipated that the absolute amounts extracted and the amount of traffic associated with the operation will not exceed the original approval. One major change is that the original above water extraction would have concluded with land restoration that returned the land to agricultural uses. Under this proposed change, the disturbances will be greater and that will not be possible. Plans have been made to create a lake at the extraction site, which could maintain new and diverse ecosystems and activities. There may be some increased risks to water quality in the immediate area (localities within 1km of the site), as the company is located adjacent to a river and the operations will have some groundwater impacts. These impacts are difficult to anticipate, and steps are taken to minimize them, however, they are important to consider.

Related Information

The following resources provide more information on this topic

- Planning Summary Report (link: https://www.woolwich.ca/en/township-services/resources/Ongoing-Planning-Items/Preston-Sand-and-Gravel/PTR_PlanningSummaryReportWithApp2016-07-22.pdf)
- ObserverXtra.com (link: https://observerxtra.com/2016/10/27/concerted-opposition-effort-meets-plan-go-water-mine-jigs-hollow-gravel/)

Appendix D
Statement of Software Availability

The P2P-DSS prototype software is currently available for viewing and limited-feature use online. To access P2P-DSS please use the link provided in the box below or copy and paste the address into your web browser.

P2P-DSS is currently housed and maintained at the address provided and will be accessible until at least July 1st, 2019. As a prototype software, following that date, the website may be subject to changes and interruptions due to ongoing research. If you are unable to access the website please contact Simone Philpot using the contact information provided below. If you would like to use P2P-DSS please also contact Simone Philpot for further information.

ACCESS TO P2P-DSS
P2P-DSS: http://p2psurveys.azurewebsites.net

For further information and to arrange to use P2P-DSS please contact Simone Philpot at:

Simone Philpot:
sphilpot@uwaterloo.ca
https://simonephilpot.com