UNIVERSITY OF CALGARY

A Socio-Technical Approach to Designing a Visual Analytics Decision Support Tool for Wind Farm Placement Planning in Alberta

by

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Abstract

Wind energy is recognized as an important component of the world’s energy mix. Despite its widely acknowledged advantage as a renewable energy resource, the development of wind farms in the last 20 years has posed a critical challenge for land use planning in Alberta. In view of this, there are compelling arguments that effective, place-specific decision support tools would enable stakeholders identify appropriate placement locations for wind farms in Alberta.

The research presented in thesis empirically examined ways in which a decision support tool can be developed to achieve the goal stated above. A socio-technical approach was used to identify the decision support requirements of wind energy stakeholders in Alberta and to develop a conceptual framework in response to the requirements. Further research was conducted to determine the underlying attributes of effective visual analytics decision support tools, and how those attributes can be applied to the design of the proposed tool. Based on the established requirements, attributes, and conceptual framework, a proof-of-concept, web-based Alberta Wind decision support tool (AB–WINDEC) tool was implemented using iterative prototyping techniques.

The prototype was first assessed through an expert appraisal. It was subsequently evaluated in focus groups with wind energy stakeholders in Alberta. Focus group participants reviewed the conceptual system design in the following areas: usability, usefulness, analytical support, and capability to support tasks and data management. These findings suggest that AB–WINDEC can be useful for educational purposes, public engagement, high-level analysis, risk assessment, and collaboration.

The main contributions of this thesis and the research described in it are four-fold: It extends current knowledge by bringing together, for the first time, the decision support requirements of
stakeholders involved in planning the placement of wind farms in Alberta. Thus, it was possible to develop a conceptual framework that integrated the dual aspects of AB–WINDEC as a social and technical decision support tool. Progress was made in multi-disciplinary areas of visual analytics, product design, product experience, prototyping, and design research. Finally, the thesis shows that knowledge gained from empirical research can inform the development of an effective visual analytics decision support tool.
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Dedication

For the distinguished triumvirate

Sheelagh Carpendale and Richard Levy and Cormack Gates
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‘Everyone designs who devises courses of action aimed at changing existing situations into preferred ones. The intellectual activity that produces material artifacts is no different fundamentally from the one that prescribes remedies for a sick patient or the one that devises a new sales plan for a company or a social welfare policy for a state.’ (Herbert Simon, 1988).
Chapter One: A Research Agenda for the Development of a Wind Farm Placement Decision Support Tool in Alberta

1.1 Introduction

The development of wind farms during the last 20 years has posed a critical challenge to land use planning in Alberta. Because a wind farm can contain several hundred wind turbines and cover hundreds of square miles (Leung and Yang 2012), their planning and building frequently poses problems for land use planning. One such problem, and often one of the most difficult to resolve, is the selection of locations where these wind farms can be built (Ramírez-Rosado et al. 2008).

At the heart of this land use planning problem is the need to protect public interests and to weigh these interests against the rights and interests of individuals and private organizations who are proponents of wind farm development (Chernoff 2015; Coles and Taylor 1993; Fabos 1985). In Alberta, there is currently much debate about the potential impacts of wind farms on other land uses (Alberta 2008; Armstrong et al. 2005; Cheryl and Marilyn 2010; Ingelson and Kalt 2010; Johnson et al. 2011; Macarthur 2010; Weis et al. 2010). As public concern about the impact of wind farms has grown, conflicts between public and private interests are also on the rise. This scenario, according to Khan (2003), creates a challenge on how to make the right decisions.

However, the process of selecting appropriate placement areas wind farm sites requires consideration of multiple, complex, and interrelated phenomena (Cathcart 2011). It is also characteristic of wind farm placement planning in Alberta that the decisions involve many planners, regulatory officials, industry developers, conservationists, municipal officials, public interests groups and organizations (Thibault et al. 2013). I refer to these sets of people as
Stakeholders. Stakeholders come to the decision process with different preferences, different values, and knowledge. The background to these decisions are also influenced by different social, economic, and political factors that underscore the need to improve ways of analyzing complex information (Dye and Shaw 2007; Kiker et al. 2005).

In view of these challenges, some studies have identified the use of decision support tools as one of the promising solutions that can aid multiple stakeholders in understanding complex information when assessing potential wind farm placement locations (McKeown et al. 2011; Moiloa 2009; Ramírez-Rosado et al. 2008). Part of the attributes of such tools, according to Moss et al. (2014), is their ability to harness vast data sources, facilitate data storage, access, analysis, and visualization. Harnessing the power and potential of decision support tools could help focus attention on the real issues that inform the decisions on placement locations for wind farms (Cathcart 2011), and could thus enhance capacity for evaluating placement alternatives.

Clearly, both the results of the decision-making process and the tools that facilitate the process are important considerations in the Alberta context. Dozier and Gail (2009) point out that effective decision support tools could lead to more satisfactory decision-making processes and outcomes if their development process is guided by empirical research. It is, therefore, worthwhile to consider the conditions required to successfully develop tools that could be useful to stakeholders in the manner described above.

1.2 Motivation and Challenges

A decision support tool is a computer-based system with interactive capabilities intended to enhance the ability of stakeholders to analyze complex information and make decisions (Power et al. 2011). Power et al.’s definition adequately describes the current application of decision
support tools in Alberta where the wind farm placement planning process can be said to involve multiple stakeholders engaged in various information-processing tasks leading to decision-making.

However, a number of barriers restrict application of decision support in the wind farm planning decision process in Alberta. One major barrier is the dichotomy that exists between the requirements of stakeholders and the tools that are being developed to support stakeholders (Davey and Cope 2008). More particularly, the lack of fit in terms of usability, planning processes, handling of data, analytic aids, and tasks support has meant that existing decision support tools are rather limited in their decision support capabilities (Sprague and Watson 1993). Heathfield and Wyatt (1993) also provide an analysis of what they consider to be the barriers that explain the lack of use of decision support systems. Their opinion is that most systems have not been designed to address the problems that stakeholders actually face, and often do not take their work flow processes into account. For example, in arriving at decisions, stakeholders have to consider social, economic, environmental, and legal implications of any course of action. However, information needed by stakeholders is frequently not available or in the right form. These shortcomings are certainly applicable to the decision support tools currently available to stakeholders in Alberta, and can be traced to a lack of understanding of stakeholders needs, knowledge of the land use issues, and the purpose which the tools are meant to serve (Goguen and Linde 1993; Zowghi and Coulin 2005).

What is clearly conveyed from the above discussion is the ambiguity in the use of the phrase ‘decision support’ and how it applies to the process of planning placement locations for wind farms in Alberta. On the one hand, there is a scientific and technological pressure towards enhancing capability of tools that facilitate placement decisions. On the other are social concerns
about preserving other forms of land use in relation to wind farm placement decisions. Both views are relevant to this work. Therefore, before defining the research thesis, it is necessary to discuss six key areas where the empirical knowledge needs to be developed or expanded. These are:

- Coverage and integration of place-specific issues
- Understanding the decision support requirements
- Adopting a socio-technical approach to design
- Setting the standards of decision support tool development
- Designing for decision support in the wind farm placement planning process
- Evaluating for usefulness

Each of these challenges is discussed below.

1.2.1 Coverage and integration of place-specific issues

A feature that most wind farm placement planning processes have in common, in addition to being spatially-explicit, is that they have multi-criteria issues that require consideration (Talinli et al. 2011). Research to understand these issues, how they are perceived and explained by the stakeholders, and how decisions can be improved, must draw on the contextual values that people form with places.

This brings to fore the challenge of and integrating place-specific issues and locally-appropriate data into the development of decision support tools (Keeney 1992; Andrienko et al. 2003; Bagstad et al. 2013). Although the term ‘place-specific’ is not well-defined as a resource management and decision support concept, it has been turning up in a number of academic
discussions in planning theory and practice, for example, (Carrus 2005; Cresswell 2009; Friedmann 2010; Nordström et al. 2011; Bagstad et al. 2013; Creutzig et al. 2013).

As a geographic term, place-specific refers to a sense of place that has meaning and value to people (Williams and Stewart 1998). Place-specific can also be defined as a social construct formed around shared identity, and information affecting the specific features or the distinctiveness of a given territory (Carrus 2005).

These definitions have some bearing on the dynamics of wind farm placement decision making in Alberta. To be effective in locally-accountable processes, Snyder (2003) and Jankowski et al. (2006) argue that decision support tools should be linked to place-specific issues. Linking place-specific issues would make data processing and integration more easier, and could thus lead to tools that are perceived as useful by stakeholders (Briane 2004). However, this would require a higher level of coverage and development than what is currently offered by generic tools (Breiter and Light 2006).

1.2.2 Understanding the decision support requirements

Kaner et al. (1999) defined a requirement as an objective that must be met. This definition is important for a number of reasons. First, it highlights the notion of an objective or goal or necessary characteristic that motivate the development of a decision support system. The definition also refers to a kind of formal specification that can serve as a valuable focusing mechanism for future design and development efforts.

According to Nuseibeh and Easterbrook (2000), the primary measure of success of a system is the degree to which it meets the purpose for which it was intended. From the software systems point of view, requirements engineering is the process of discovering that purpose, by identifying
stakeholders and their needs, and documenting these in a form that is amenable to analysis, communication, and subsequent implementation (Hull et al. 2010). When the design process unfolds, requirements can be formulated, explored, and evaluated against the needs that gave rise to them (Loucopoulos and Prekas 2003). From a methodological perspective, requirements provide an obvious tool for assessing the usefulness of a decision support tool, because evaluation can determine whether the requirements have been met (Browne and Rogich 2001).

Nevertheless, a traditional view in the field of product development is that requirements are often not needed from stakeholders prior to design (Baxter et al. 2008; Marshall et al. 2013; Metersky 1993). This is perhaps why some designers approach a design process with an assumption of knowledge, whereby the systems are built top-down, and stakeholders’ requirements are only incorporated towards the end to embellish the development process (Lu and Cai 2000). This approach, according to Crist (1998), ignores the most important element which is to build systems from real needs by understanding the stakeholder’s decision process, what data is needed for that process, and how that data can be managed to support analysis leading to decisions. This often leads to poor requirements and a disappointing or inefficient system.

With the foregoing, there is little doubt that a design process should start with a need that must be satisfied by the creation of a physical product or system (Brace and Cheutet 2012). However, whether viewed at the systems development level or the product development level, there are difficulties associated with this approach in the context of the wind farm placement planning. Through my interactions and discussions with stakeholders, I have found that simply asking what they need does not lead to effective solutions. Stakeholders are numerous and often distributed. Their goals may vary and conflict, depending on their perspectives of the
environment in which they work and the tasks they wish to accomplish. Their requirements may not be explicit or may be difficult to articulate, and, inevitably, satisfaction of these goals may be constrained by a variety of factors outside their control. They often have limited experience with decision support tools and how to incorporate it into their decision-making processes.

Furthermore, the complex nature of the decision issues has led to an increased level of complexity of stakeholder requirements (Sharma and Pandey 2014). As such, requirements tend to change through the course of a decision process, especially when there are different stakeholders and stages involved (Coughlan et al. 2003). This creates additional difficulties when translating the requirements into design solutions. In addition, stakeholders are more exposed to modern interactive devices, and thus have a greater range of capabilities and requirements than ever before (Macdonald 2006).

These scenarios must be considered when providing decision support tools for wind farm placement planning in Alberta. Since decision support requirements must span the gap between the social aspects of stakeholder needs, and the technical aspects of software behaviour, the key question is not whether to elicit the requirements, but how to elicit, understand, and translate the requirements into purposeful and logical tools.

1.2.3 Towards a socio-technical approach to design

A fundamental challenge for designers is to deal with the fact that people and technology are different (Benyon et al. 2010). Research in decision support systems has only recently begun to explore stakeholder requirements as an integral part of the process that supports the development of a decision support tool (Williams et al. 2007). Most software development efforts tend to focus on developing functionality and controllability, but do not always consider performance,
experience of use, application workflow, and the social and organizational context in which systems are used (Carroll and Hall 2002). Patterning their methods after those in the engineering sciences, systems designers have generally adopted the technical approach. Wind turbines, the argument goes, are more or less technical equipment, serving technical purposes, and requiring technical knowledge to oversee the placement decisions. What is often excluded from this argument is that decision-making processes about wind farm placement planning also involve people, and will thus have social, economic, environmental, and political implications. In actuality, a more complete view is one that recognizes the interaction between people and technology in a decision-making process. A concept that is central to this view is the “socio-technical approach” (Hasan 2006; Bryl et al. 2009; Carlsson 2010; Miah et al. 2012).

Socio-technical approach to design is an approach that aims to give equal weight to social and technical issues when new work systems are being designed (Trist and Bamforth 1951; Mumford 2000). Some authors have described the socio-technical approach as a principle that should drive the design and development of effective decision support tools (Mumford 2006; Respício et al. 2010). The socio-technical approach to design holds that direct participation of stakeholders in the system design process is required because decision-making processes are often guided by social factors and needs (Scacchi 2004). Coakes (2002) also stressed the importance of the linkages between social requirements and technical design in terms of developing systems that can support the creativity of stakeholders in decision-making. The socio-technical approach places greater emphasis on the participation of stakeholders, and the evolution of an iterative implementation methodology (Bryl et al. 2009; Whitworth and Ahmad 2012).
The socio-technical approach therefore is about joint optimization, with a shared emphasis on achievement of both productivity in technical performance and usefulness of a technology in decision-support settings. Figure 1.1 illustrates this concept with a model that links social requirements with the technical design of decision support tools.

![Social Requirements -> Technical Design](image)

**Figure 1.1. An approach to socio-technical design**

The socio-technical approach has been used to construct decision support tools in the past, and some examples of the approach can be found in the literature: Cox (1996) conducted a case study of a cotton pest management system used in Australia between 1980 and 1993. Lu and Cai (2000) developed a prototype system that uses advanced networking techniques to support stakeholders’ interaction in collaborative design. Applying a socio-technical system approach, Shin (2010) implemented a socio-technical framework to assess and predict the development of cyber-infrastructure (CI) in Korea.

The above case studies provide some fine examples of combining the social and technical aspects of design. We see from the case studies (not discussed in detail here) that there are established precedents where social requirements have been translated into useful technical designs in decision support problems. However, a significant research challenge is how to extend this approach to the development of decision support tools for wind farm placement planning in Alberta.
1.2.4 Setting the standards for development of decision support tools

The pressures driving design practice in this direction seem urgent because they derive from increasing demand for software products that are reliable and useful for the purpose which they were created (Booker et al. 2001).

The focus on standards and quality improvement is not misplaced. Much of the prior research focused on demonstrating the capability of tools in improving decision outcomes (Phillips-Wren et al. 2011). However, currently, there is a dearth of well-defined techniques or consensus approach to designing decision support tools or in evaluating the effectiveness of available tools (Zapatero 1996; Newman et al. 2000; Mysiak et al. 2005).

Particularly in the context of wind farm placement planning, standards are needed to show how the attributes of a tool can improve the knowledge of stakeholders involved in the decision-making process, and how to identify those performance attributes that can enhance the effectiveness of decision support tools. Identifying the useful attributes and their underlying metrics can be help clarify the foundational design and evaluation goals prior to development, and can also help designers assess the usefulness of decision tools against the stated goals (Alben 1996).

1.2.5 Designing for decision support in the wind farm placement planning process

The complexity of decision support problems like wind farm placement planning makes necessary the development and application of new tools capable of incorporating not only numerical data, but also qualitative information used by stakeholders involved in the decision-making processes (Poch et al. 2004). This problem presents a particularly difficult challenge for systems designers (Carlsson et al. 2011; Perini and Susi 2004). This, perhaps, is partly due to the
lack of well-defined methodology or frameworks guiding the design of decision support tools (Miah et al. 2012).

Many have argued that conceptual design frameworks are needed to adapt tools to the decision process, incorporating the main decision issues, handling data, and engaging stakeholder background knowledge and preferences (Leeuwen and Timmermans 2006; Maguire 2001). Given the pace of technological advancements, the possibilities for visual representation, interactive map-based decision support tools, interactive prototyping and other ways of presenting design ideas are emerging as viable options for research.

1.2.6 Evaluation for usefulness

Evaluation is a crucial component in the design of decision support tools (Hevner et al. 2004). Critical perspectives in research have pinpointed certain problems surrounding the evaluation of decision support tools. A number of prominent researchers have made some excellent observations that I want to reference as well. Sojda (2007) contends that decision support tools designed to handle complex and poorly structured problems are often not empirically evaluated. Similarly, Newman et al. (2000) noted that evaluation is underrepresented in research concerning decision support systems. In the view of Mysiak et al. (2005), what is generally lacking is a consensus about what evaluation methodology to use or what features to assess in the evaluation of decision support tools. Sprague and Carlson (1982) argue that evaluation of a decision support system should be treated as a research activity, which should focus on ‘value analysis’. Eason (2005) and Baecker et al. (1995) recommend that iterative prototyping methods should be used for decision support system development.
Thus a critical challenge that needs to be addressed is how to evaluate decision support tools for efficiency, performance, utility and perceived usefulness (Hevner and Chatterjee 2010). Measures of usability have value, but they tell only part of the story. A highly usable system is always likely to be rejected if people perceive it as not useful to their tasks and processes. I argue that evaluation should pervade the process of requirements gathering, conceptualization, design, and implementation, with the ultimate aim of addressing the question: Was the system useful for its intended purpose?” Often, designing the right approach to evaluation can be as important as designing the decision support tool. This task is not made easier because assessing the usefulness of a decision support technology, according to Scholtz (2006), would require going beyond traditional usability evaluations.

Benyon et al. (2010) views the people who use a technology as the most important component in the evaluation process. While it is important to evaluate the usability and functionality of a decision support technology, an evaluation approach should also be concerned with usefulness of the technology to the people who use it. In this context, selecting the appropriate evaluation method and identifying the attributes to be measured are two key challenges that needs to be addressed.

1.3 Thesis statement

The previous discussion has provided a brief look at some of the existing situations and challenges that should be considered in development of decision support tools for wind farm placement planning in Alberta. Each challenge presents a unique opportunity for research. Although there are no comprehensive empirical research studies that have looked at the
relationship between the social and technological aspects of decision support in the Alberta wind farm placement domain, I feel confident in stating the following:

*That taking a design approach that prioritizes the needs and requirements of the stakeholders who will use the tool, rather than focusing only on what the technology can do, will more likely lead to a more effective decision support tool for wind farm placement planning in Alberta.*

In this context, I define 'an effective decision support tool' as a tool that is perceived as usable and useful by the people who use it. The broad questions this thesis asks then are, how might we design decision support tools to support stakeholders in planning the placement of wind farms in Alberta? More specifically, what research frameworks and design techniques can inform the development and implementation processes of such decision support tools?

Following Hevner et al.’s (2004) model of designing decision support tools, this thesis aims to gain an understanding of the requirements needed to make an informed intervention in the design of decision support tools useful for wind farm placement planning in Alberta.

**1.4 Purpose of the study**

The overarching purpose of this thesis is to develop an effective decision support tool that can be used by stakeholders to identify appropriate placement locations for wind farms in Alberta, including the assessment of potential impacts of wind farms on land use. In achieving this purpose, the challenges and gaps highlighted in section 1.2 require a focused research approach to improve current understanding and knowledge.
1.5 Research and Development Methodology

The development of systems, especially the development of decision support systems, has to follow a certain research process and conform to some criteria to meet the rigor of academic research (Nunamaker and Chen 1990).

To achieve the purpose of this research, I have articulated the 'research and development' methodology to systematically respond to the challenges discussed in section 1.2. Blake (1978) defined the ‘research and development' methodology as a research process where empirical knowledge gained through the research will be used to produce ‘...useful materials, devices, systems, or methods, including design and development of prototypes and processes’. The environment for this research is built on design theories, field investigations, and product development methods. The research and development methodology aligns with Nunamaker and Chen (1990) view that ‘without development, research has no use; and without research, development has no base’. It is similar to the ‘design study’ methodology used in visualization research, in which researchers analyze a specific real-world problem faced by domain experts, design a visualization system that supports solving this problem, validate the design, and reflect about lessons learned in order to refine visualization design guidelines (Sedlmair et al. 2012).

Borrowing from Nunamaker and Chen's (1990) work in the field of system development methodology, I have developed a research and development model for this thesis (see Fig. 1.2). The model illustrates the connections between the five elements of the research and development approach, namely: requirements elicitation; development of the conceptual framework, design, implementation, and evaluation. Using this model, I will develop a framework of design to integrate the dual nature of decision support tools development as a social and technical endeavour. Product design research in interdisciplinary areas will be reviewed to provide a basis
to argue that the process of designing effective decision support tools should be guided by specific attributes and standards. Knowledge gained from the research will be used to guide development. Following the implementation of the prototype, empirical methods will be used to evaluate how well the prototype satisfies the intended requirements and to determine how useful the prototype is to the intended stakeholders.

It is likely that this approach will lead to important contributions in design and decision support systems research. In addition, some generalizable results can be expected from the experiences gained from designing and developing the tool.

Figure 1.2. The Research and Development approach (adapted from System development research model Nunamaker and Chen 1990; Nunamaker et al. 1991)
1.6 Research Objectives

Following the research approach, the research purpose is addressed by the following six research objectives:

I. Identify the contextual issues that influence decision-making in wind farm placement planning in Alberta.

II. Identify the stakeholders’ decision support requirements for wind farm placement planning in Alberta.

III. Determine the attributes of useful decision support tools through state-of-the-art investigation and recommend criteria to guide design and evaluation of decision support tools applicable to wind farm placement in Alberta.

IV. Develop a framework that incorporates I, II, and III, and lay out specifications for a wind farm placement decision support tool in Alberta.

V. Design and implement a proof-of-concept prototype decision support tool that integrates the relevant information and analysis tools to support stakeholders in identifying appropriate placement locations for wind farms.

VI. Evaluate the utility and effectiveness of the prototype as a tool in wind farm placement decision-making with stakeholders to assess how well the prototype meets their functional goals and usability needs.

1.7 Thesis structure and methods

The work in this thesis aligns strongly with Simon's (1988) argument, that ‘everyone designs who devises courses of action aimed at changing existing situations into preferred ones’. The thesis consists of a collection of four research papers, two of which have been published in peer-
reviewed journals. Given the multidisciplinary nature of the research, the thesis is written mostly to cover the new ideas and the fundamental concepts needed to contribute to theoretical and practical knowledge in the design of decision support systems. The chapters in this thesis have a common aim — to develop tools that successfully meet the needs of stakeholders who use them. A key part of achieving this aim is to gain a good understanding of the stakeholders’ needs and the ways in which they use systems. This includes identifying the features they enjoy as well as those they dislike, or which cause them problems. This approach will result in a successive refinement to the prototype system and its development process.

Even though the chapters are independently-shaped, they are purposively linked in achieving the objectives of the thesis.

The rest of the thesis is organized as follows:

*Chapter 2: Decision support requirements for wind farm placement planning in Alberta (objective 1 and 2)*

Chapter 2 presents the findings of a field study which elicited a wealth of information on the range of issues concerning wind farm placement and the decision support requirements of stakeholders in Alberta. Based on the findings, it proposes a list of recommendations that focus the design choices on the stakeholders’ requirements and highlight the relevance of a place-based decision support tool with visual and analytical attributes.

- Data collection Methods: Questionnaires; Semi-structured interviews.
- Analysis methods: Inductive analysis approach; descriptive statistics.

*Chapter 3: Towards a product design assessment of visual analytics in decision support applications: a systematic review (objective 3)*
Due to the proposed visual analytics character of the wind farm placement decision support tool in chapter 2, it was important to systematically review the historical patterns in the design and implementation of visual analytics tools from 2006 to 2012 in chapter 3. Using decision support as a case study, chapter 3 discusses the timeline of visual analytics research in real-world applications.

It explores the roots of product design and development in the field of visual analytics. There is some discussion as to the attributes of effective decision support tools and how these can be incorporated in the design, implementation and evaluation stages. The chapter argues that the experience of use and effectiveness is shaped by the ability of the decision support tool to support creativity, utility, situation awareness, collaboration, and interaction. It compares the existing visual analytics decision support systems with the characteristics of the ideal decision support tools. Chapter 3 contributes to the overarching objectives of the thesis by giving generalizable attributes for evaluating the effectiveness of visual analytics decision support tools. These attributes are distinguished in having their own underlying metrics and could serve as the first tentative steps in standardizing the design and evaluation of visual analytics decision support tools.

- Data collection methods: Bibliometric research techniques.
- Analysis methods: Content analysis.

Chapter 4: A prototype visual analytics decision support tool for wind farm placement planning in Alberta (objective 4 and 5)

Chapter 4 presents the design and development of the web-based Alberta Wind Decision support tool (AB–WINDEC) prototype. This prototype is informed by the decision support
requirements of stakeholders drawn from chapter 2 and the design attributes that were developed in chapter 3. The chapter reports on the design techniques and the socio-technical framework used in implementing the AB–WINDEC prototype. These include:

- Design methods: Requirements specification; conceptual framework.
- Implementation methods: Iterative prototyping; web-based integration.
- Evaluation methods: Expert appraisal.

These approaches are grounded in principles and methods drawn from the fields of human-centred design research, experience design, product design, and visual analytics. The chapter adds to current knowledge on, (1) how to translate stakeholder requirements into realistic design concepts to drive effective decision support tool development, and (2) how to implement these design concepts using low-fidelity prototypes and medium fidelity prototypes.

Chapter 5: Design evaluation of a prototype decision support tool for wind farm placement planning in Alberta: Results from a focus group study (objective 5)

Chapter 5 demonstrates the use of focus groups as an effective technique for evaluating the utility of a decision support tool prototype. The chapter reports the findings of a focus group evaluation study of the AB–WINDEC prototype. It discusses the feedback from participants’ and how these could be used to develop the prototype further. The results from chapter 5 attempts to improve current understanding of how stakeholders interact with tools and what is required to effectively support wind farm placement decisions. Finally, the findings provides insight into factors that could potentially influence the integration and use of AB-WINDEC.

- Data collection methods: Focus groups; questionnaires; experimental sketch paper technique.
• Analysis methods: Margin coding analysis approach; descriptive statistics.

Chapter 6: Conclusions

Lastly, Chapter 6 summarizes the findings of this thesis and discusses these findings in the context of each research objective outlined in Chapter 1. Main contributions of this research are then offered together with practical suggestions, design implications, and recommendations for a continuing line of research that will work towards developing effective decision support tools for wind farm placement planning in Alberta.

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Chapter Two: Decision Support Requirements for Wind Farm Placement Planning in Alberta

Abstract

Current trends in Alberta require the involvement of multiple stakeholders and decision support tools in planning the placement of wind farms. While the use of decision support tools can assist stakeholders in making decisions, developing useful tools for a domain as complex as wind farm placement planning is challenging. In addition, few design requirements exist to ensure that decision support tools are specific to local needs, and that they have capabilities to support stakeholders in making informed decisions about placement locations. To this end, we conducted a study, using questionnaires and interviews to, (i) identify the main issues that influence wind farm placement and land use decisions in Alberta, (ii) identify stakeholder’s decision support needs for evaluating wind farm placement decisions and how these needs can be incorporated in a decision support tool, (iii) gain a deeper understanding of how stakeholders in Alberta currently interact with existing tools and identify areas where design can improve usability, and (iv) derive usability attributes that can inform the development of a decision support tool for wind farm placement planning in Alberta. Based on the study findings, we propose some design recommendations which highlight the relevance of a place-based decision support tool with visual and analytical attributes.

2.1 Introduction

The placement of wind farms has been described as a land-use planning process involving complex decisions on how to manage the environment, landscape, economy, and social and economic interests (Ramirez-Rosado et al. 2008; Simão et al. 2009). In Alberta, one of the
important objectives of this process is to identify appropriate areas where wind farms can be
built, with reference to other land uses and public values. A placement decision can be difficult
because of the involvement of multiple stakeholders with different backgrounds and conflicts
among varying interests (Klepinger 2007; Keim et al. 2008). In addition, wind farm placement
planning, like many land-use problems, is burdened with significant issues that are not easily
quantified, such that potential solutions are uncertain (Couclelis and Monmonier 1995).

The realization that such complex processes require different approaches has led to the
growing acceptance of decision support tools as a better way of making placement decisions
(Fedra 1993; Jankowski et al. 2006; Lammeren et al. 2009). A decision support tool is defined as
an interactive computer-based information system that is designed to facilitate solutions on
decision problems (Thomas and Nejmeh 1992; Shim et al. 2002). Decision support tools are,
therefore, developed to increase stakeholders’ knowledge and to augment their ability to analyse
information on alternative courses of action, leading to the selection of the best option (Davis
and Stoms 2001; Gill et al. 2010; Sauter et al. 2011). The intended advantage of using decision
support tools is to enhance stakeholders’ understanding of the overall effects of placement
decisions (Arciniegas et al. 2013).

In the past few years, a number of decision support tools have been developed to assist
stakeholders in land-use decision-making. However, an essential consideration is that a decision
support tool should provide information about resources that are specific to the local context and
needs (U.S. Environmental Protection Agency 2005). Existing land-use decision support tools
often fail to achieve acceptable performance levels because they are not optimally designed to
suit the preference of stakeholders, and often do not display relevant data in appropriate contexts
or in formats that are integrated into their work environments and task flows (Clegg et al. 1997; McBride 1997; Newman et al. 2000b).

A number of authors have identified the need to explore the socio-technical gap of local wind energy developments, the physical and environmental characteristics that are linked to placement decisions, the role of stakeholder values and how all of these aspects influence stakeholder decisions (Pasqualetti 2001; Bell et al. 2005; Pedersen and Larsman 2008; Swofford and Slattery 2010; Pasqualetti 2011). Jankowski et al. (2006) and earlier work by Keeney (1992) also suggest that incorporating stakeholders’ information needs during a decision process require the understanding of stakeholders’ knowledge of issues. Some notable studies suggest that decision support tools should be developed within local domains (Luconi et al., 1993), to integrate contextual information and tasks in the decision-making process (Antunes et al. 2014). Bennett (1976) argued that the incorporation of local stakeholder background knowledge, contextual data, work tasks and stakeholder usability requirements can significantly improve the usefulness of a decision support tool. These strategies can help a designer to develop a realistic understanding about system capabilities required by stakeholders, and will also ensure broader integration of the tool into real world settings. Given Alberta’s unique scenic qualities, native prairie grasslands, regulatory oversight, and continued development and expansion of the wind energy industry, stakeholders in Alberta need effective decision support tools that can enhance their ability to identify appropriate placement locations for wind farms.

As a first step towards addressing this need, we present the results of a study in which we investigated stakeholders’ views on decision support requirements for wind farm placement in Alberta. We approach the enquiry primarily from a qualitative perspective, in view of the growing acceptance of qualitative research as a better way to handle complex and dynamic
environments (Salomon 1991), such as wind farm placement planning. In addition, the enquiry was augmented by demographic data collected during the study.

We have structured the study to achieve four main objectives: (1) to explore the main issues concerning wind farm placement and land use decisions in Alberta; (2) to identify the stakeholders’ needs for evaluating wind farm placement decisions, and how these needs can be adapted in a decision support tool; (3) to gain a deeper understanding of how stakeholders in Alberta currently use existing tools, and identify areas where design can improve usability; and (4) to assess usability attributes that can inform the development of a decision support tool for wind farm placement planning in Alberta.

The remainder of this chapter is organised as follows. In section 2, we discuss related work in requirements analysis done in other decision support domains with diverse stakeholders’ interests. Next, we present the methods used for data collection and analysis. We then discuss the results, limitations and recommendations for design. We conclude the paper with contributions that arise from the study, and directions for future work.

2.2 Related Work

According to Grady (2014), a requirement is an essential attribute or characteristic for a system. Requirements gathering is a combination of informal expression of the needs and information from several sources – often reflecting the point of view of any person or multiple persons – from which a design solution can be generated (Yaverbaum 1989; Brace and Cheutet 2012). The conversion of these requirements into well-defined design recommendations is a key step in a design process (Coleman et al. 2007).
The concept of requirements gathering has been adopted in decision-making domains to facilitate the design and development of decision support tools (Elm et al. 2005; Papathanasiou and Kenward 2014). For example, findings from Crist (1998) and Hevner et al. (2004) show that the most important and obvious need, when designing a decision support tool, is to understand the decision maker’s decision process, what data are needed for that process and how those data must be packaged to support the decision makers in their tasks. This view is shared by Ackoff (1989), who recommends that stakeholders participate directly in design projects that concern them.

A literature review indicates some research investigations designed to understand the needs of stakeholders for decision support systems in domains with diverse stakeholders’ interests and semi-structured tasks. Andrienko et al. (2003) conducted a series of field experiments from which they observed that different decision-making domains have different processes and data criteria that require distinct decision support tools.

Chamberlain et al. (2012) also integrated context-specification information in the design of a decision support system for alternative wastewater solutions. Farooq et al. (2009) reported on a requirements gathering study for the CiteSeer collaborator decision support tool. Their findings were published in the form of design recommendations that can be implemented in a prototype. In land-use decision-making, Jankowski et al. (1997) elicited design requirements from a range of stakeholders on their decision tasks, site selection preferences, interface and functionality needs. From their findings, the authors proposed key design guidelines for development of the land-use decision support tool. Perini & Susi (2004) also conducted a requirements study to aid the design of a decision support system devoted to support decision-making when managing
apple plant diseases. Denzinger & Ruhe (2004) developed and demonstrated a novel approach for obtaining stakeholders’ requirements for decision support in software release planning.

These studies provide a useful foundation for our work. However, while the concept of requirements gathering has proved useful in guiding the design of effective decision support tools in diverse applications, to our knowledge it has not been applied to the domain of wind farm placement – more specifically to the Alberta context. In addition, rapidly evolving technology has increased the level of complexity of stakeholder requirements. For example, in the Alberta wind farm placement domain, decision support requirements must draw from changing needs, changing demographics and personas of stakeholders, siting constraints and regulations. The foregoing points to a need for a systematic approach to elicit stakeholders’ requirements, which can facilitate the development of a place-based decision support tool for wind farm placement planning in Alberta.

2.3 Methods

We adopted a mixed-method data collection approach to obtain an objective and subjective perspective of participant views. For this research, it was also important to obtain a depth of meaning and to gain insight and understanding from the stakeholders’ responses; hence our decision to use a face-to-face, semi-structured interview approach. These strategies, along with the inductive analysis approach, were used to establish credibility in the findings. We describe the methods in more detail below.

2.3.1 Context

Alberta is one of Canada’s three Prairie Provinces, with a total area of approximately 661,185 km2 (AESRD 2014). The region is known mostly for its oil sands and agricultural
production, but the local wind energy industry has evolved considerably in recent years, primarily in southern Alberta (Figure 2.1).

Although municipalities and the provincial regulatory agencies make the final decisions on wind farm placement, other stakeholders are also involved. These stakeholders collaborate to make decisions about ways to use the land and access the wind resources, in reference to other land uses. These interactions provide a rich context for the use of decision support tools in making appropriate decisions that will likely affect the social, economic and environmental landscape of the province.
2.3.2 Participants

We purposively sampled 15 stakeholders working in the wind energy industry in Alberta as participants for the study. The sample included wind industry professionals, land owners, researchers, planners, regulators and consultants. We identified the stakeholders based on their experience and their level of involvement in the wind energy sector in Alberta. Specifically, the sampling approach targeted individuals who:

- Have demonstrated interest in the placement of wind turbines in Alberta;
- May be affected, or believe that they could be affected, by the placement of wind farms in Alberta;
- Can influence public opinion about wind farm placement and associated land use issues; or
- Have the authority to make land-use decisions affecting wind energy placement in Alberta.

Thus, we consider the final sample to be reasonably representative of our overall target population, and it forms a good basis for discussing wind farm placement issues and decision support needs. Participants were quite motivated to give their views and did not receive any compensation for their participation.

2.3.3 Pilot Study

Following our research design, we conducted a pilot study from October to November 2013. The session involved a gaming software designer and land owner, two PhD students from the Computational Media Design programme, and a PhD student with a background in environmental design, at the University of Calgary. We used the pilot study to assess the
interview and the survey questionnaire. This was very helpful because it highlighted some shortcomings in the layout of questions. Following the pilot study, we refined the interview and survey questions.

2.3.4 Data Collection

We contacted the participants through emails and phone calls to schedule the interviews. We conducted the interviews on a one-to-one basis using our research lab at the University of Calgary, the participants’ offices or other convenient locations, between November 2013 and February 2014.

Prior to the start of the interview, we asked the participants to sign a consent form granting permission for the interview to be recorded. We also gave them the opportunity to ask questions about the study. We then asked each participant to complete a pre-interview survey questionnaire of 12 questions. The survey questionnaire included questions pertaining to demographic data and self-reported levels of internet usage, data sources, software usability preferences and job responsibilities.

The interviews were semi-structured and lasted between 30 and 60 min on average. We recorded the interviews on an audio tape. In the interview, we encouraged participants to discuss their views on wind farm placement issues, their backgrounds and expertise, and their interest in the issues. We also asked them for information about their work tasks, the tools they currently use and their information needs. We then transcribed the interviews verbatim and removed all personal identifiers from the transcripts.
2.3.5 Coding and analysis

We used the inductive approach, as suggested by Thomas (2006), to code and analyze the qualitative data. Inductive approaches are intended to aid an understanding of meaning in complex data through the development of summary themes or categories from the raw data (Thomas, 2003).

We carried out the analysis through multiple, close readings and coding of the transcripts to develop themes in the data. To check the consistency of the coding, we used the following procedure: one member of the researcher team completed an initial reading and open coding of the raw transcript data based on the research objectives, grouping the texts under such categories as ‘placement issues’, ‘tasks’, ‘data requirements’, ‘existing tools’, ‘usability requirements’, ‘personas’ and ‘background knowledge’. A second researcher then evaluated the research objectives, the categories developed by the first coder and the descriptions of each category, without reviewing the raw transcripts. The second researcher was then given a sample of the coded text and asked to match sections of the text to the categories that have been developed. We compared the extent to which the second researcher matched the same text segments to the initial categories developed by the first coder. Overall, the level of matching between the categories and text by the second researcher was consistently high at over 90%. We resolved any differences through discussions. We also compiled the demographic questionnaire data in SPSS for statistical analysis.

In summary, the analysis of text, codes and themes in this study involved several iterations before moving to an interpretive phase.
2.4 Results

In this section, we first describe the demographics of the participants. Then we present the results that emerged from the qualitative and quantitative analysis.

2.4.1 Demographics

Fifteen participants completed the study (twelve men and three women). As illustrated in Table 2.1, most participants (66.6%) reported they spend at least 32 h of their work week using computers. Given that the standard work hours per week are 37.5, the implication is that 85.3% of their work tasks are performed on computers. Overall, 46.7% of the participants reported accessing information about wind farms on the internet ‘very often’, while 26.7% indicated that they always access information on wind farms via the internet.

2.4.2 Stakeholder personas

Personas are empirically formed abstractions of real users of a product who share common characteristics and needs (Pruitt and Grundin 2003; Guenther 2006; Pruitt and Adlin 2006). To help us understand the decision support requirements of the different wind energy stakeholders in Alberta, it was necessary to identify the features and characteristics that made them unique. A stakeholder persona can be represented through an archetypical fictional individual, who in turn represents a group of real stakeholders with similar characteristics (Ketamo and Kiili 2010).

Personas can be based on demographic and biographical characteristics of users (Junior and Filgueiras 2005). Both the survey and the interview data suggest that participants had a rich and varied background and expertise in wind farm placement planning. From the demographic data reported in Table 2.1, the majority of the participants indicated their primary job responsibilities as ‘analysis’, ‘regulation’ and ‘management’.
We used the process of segmentation to classify the different stakeholders based on their characteristics, needs, and motivations. Segmentation is a technique of grouping of people or organizations that share one or more characteristics, and to show how the personas can be used to inform requirements, design and implementation decisions (Junior and Filgueiras 2005; Koltay and Tancheva 2010).

Table 2.1. Demographic profile of participants

<table>
<thead>
<tr>
<th>Variables</th>
<th>(N=15)</th>
<th>n (%)</th>
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<td>(80)</td>
</tr>
<tr>
<td>Female</td>
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<td>(20)</td>
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<td>24-32</td>
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<td>(26.7)</td>
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<td>(33.3)</td>
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<tr>
<td>40+</td>
<td>5</td>
<td>(33.3)</td>
</tr>
<tr>
<td>Use internet to access wind farm information</td>
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<td></td>
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<tr>
<td>Always</td>
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<td>(26.7)</td>
</tr>
<tr>
<td>Very often</td>
<td>7</td>
<td>(46.7)</td>
</tr>
<tr>
<td>Sometimes</td>
<td>2</td>
<td>(13.3)</td>
</tr>
<tr>
<td>Rarely</td>
<td>1</td>
<td>(6.7)</td>
</tr>
<tr>
<td>Never</td>
<td>1</td>
<td>(6.7)</td>
</tr>
<tr>
<td>Primary job responsibilities</td>
<td>(N=15)</td>
<td>n(μ)</td>
</tr>
<tr>
<td>Research</td>
<td>3</td>
<td>(0.20)</td>
</tr>
<tr>
<td>Regulation</td>
<td>6</td>
<td>(0.40)</td>
</tr>
<tr>
<td>Design</td>
<td>5</td>
<td>(0.33)</td>
</tr>
<tr>
<td>Analysis</td>
<td>7</td>
<td>(0.47)</td>
</tr>
<tr>
<td>Management</td>
<td>8</td>
<td>(0.53)</td>
</tr>
<tr>
<td>Other*</td>
<td>4</td>
<td>(0.27)</td>
</tr>
</tbody>
</table>

* = Finance, Policy making, Stakeholder engagement, and Wind farm construction
Based on both the qualitative and demographic data, we were able to segment and group similar people together into stakeholder personas who will be the primary users of the decision support tool:

(a) **A developer** is one who invests in the development of wind farms. In Alberta, they often come in the form of energy companies, banks or business professionals. They are mostly interested in exploiting the wind resource or marketing the generated power. Despite their considerable investment, wind farm developers have to comply with the provincial and municipal regulations to get approval to build wind farms. Project approvals also depend on the community and land owner’s acceptance. As one developer put it: ‘We need a social licence to operate’.

We found that developers in Alberta are involved in all stages of the planning and approval process. To make their assessments on the energy yield potential from wind farms, they have to use sophisticated data analysis tools and design tools – all of which fall into the category of decision support tools.

(b) **A land owner** is a stakeholder who holds full or partial title to a piece of agricultural or native prairie land. Land owners are organized and operate collaboratively. Our data suggests that land owners in Alberta have deep economic or conservation interests in their land. A recurring theme in the responses of land owners is the significant biodiversity of the Alberta lands – specifically in southern Alberta, home to rare species of animals, and native prairie. One participant, a land owner, commented:

‘I’m interested in them from a number of standpoints: I have deep personal values about being appropriate stewards of the land and the wildlife. I have
deep personal interest in the entire southwest Alberta because, from an environmental point of view, it is one of the few remaining areas of the province where you still have significant biodiversity. There are many rare species of animals and a great deal of native prairie, and wind farms threaten all of those things in a very significant way.

Such comments suggest that land owners would like to understand the likely impact of wind farms on their properties. Thus, they require information that can help them make informed decisions on whether to lease their lands for wind farm development or not.

Based on the data, land owners in Alberta can be considered primary users of a decision support system. They are more likely to make decisions in groups. Land owners are more likely to use information tools that are publicly available to evaluate the potential impact of wind farms. These tools include published studies, application files, analytical reports, etc. They would also readily use a tool that gives clear analysis of regulatory constraints and restrictions with respect to wind farm placement.

(c) Consultants have significant analytical skills and use their expertise to perform tasks such as wind resource assessment, and generating wind farm layout designs to satisfy constraints and requirements, minimize project risks and maximize energy capture. Consultants typically do not have a vested interest in wind development projects, but are hired by wind energy companies to assist in planning the projects, in the physical design including location assessment or in contributing to information required for regulatory submissions. Nonetheless, from the data, we observed that consultants are interested in issues that affect the viability of wind energy
production in Alberta and thus require decision support tools to find a balance between constraints and viability. One of the participants, a consultant, had this to say:

‘Obviously there is sort of a balance between the constraints and the viability of the project. You know, if the constraints are too restrictive then it’s harder to do up the project. And in some cases, you know, they may be appropriately restrictive, and as a result you can’t do the project. So there’s that sort of balancing act that has to be considered.’

Consultants tend to work with land owners, developers, energy companies and regulatory officials to design the placement of wind farms. They also use various software packages and databases to perform their tasks.

(d) Pro vincial, m unicip al planning and regulatory officials: At present, data from the interviews indicate that planning officials do a lot of assessment work – reviewing applications, preparing reports, providing mitigation sign-offs – before they approve or deny wind farm development applications. One of the participants, a regulatory official, described the nature of their work thus: ‘Our job is to evaluate what is proposed in the way of development of wind turbine in relation to existing legislative or regulatory requirements and the associated guidelines that come out of it’. And in that process they tend to rely more on their experience and background knowledge of the issues that inform wind farm placement decisions.

Currently, there are multiple government agencies (e.g. Alberta Electric System Operator (AESO), Alberta Sustainable Resource Development (AESRD), and Alberta Environment) that make decisions about the placement of wind farms. There is some level of collaboration between
the agencies in the process of making these decisions. The data show that planning officials do not currently rely on tools to make their decisions.

Nevertheless, the push for renewable energy, and the complexity of environmental considerations around wind development, may increase their interest in decision support tools.

(c) Conservation groups, climate change activists and community groups are organizations lobbying for or against wind energy development in Alberta. Those against wind farm development are concerned that the operation of wind turbines would have cumulative negative effect on wildlife, prairie grasslands, scenic values, heritage sites and wild life habitat. They are concerned that ‘impacts will increase over time as the number of turbines increase’. The climate change activists, on the other hand, are pushing the agenda of wind energy as way of reducing greenhouse gas production. Members of these organizations are adept at using computers and software applications and are always actively sourcing information to support their viewpoints. As one of the participants pointed out, one of their aims is ‘to encourage informed discussion on the impacts and benefits of wind farm placement decisions’. Clearly, the activities of these groups could be aided by the use of decision support tools. Nevertheless, proprietary rights on data and the rather complicated nature of existing tools impede their use of decision support tools.

2.4.3 Wind farm placement issues

Data analysis revealed the common issues that influence wind farm placement decisions in Alberta, and how the resulting themes can be structured into a decision support tool. Participants expressed in-depth understanding of these issues. However, we found that the background of participants tend to influence their knowledge and perception of the issues. Some of the specific
perceptions around wind farm development varied significantly between groups of participants. To obtain structured responses, we asked the participants to rate a list of issues which they considered in wind farm placement planning in Alberta, and to indicate their importance on a 3-point Likert scale. Table 2.2 shows the list of the issues and the mean sum of responses to each issue.

Interestingly, effects on the ecosystem was the issue considered most significant in the interviews. Some of the participants reported their concerns about climate change and the production of greenhouse gases with fossil fuels; hence their perception of wind as a viable source of renewable energy that can help reduce greenhouse gases.

Other participants expressed doubts about the notion of wind energy as a ‘green solution’. One said: ‘My single biggest concern is that it has a great deal of negative environment impacts, and it has minimal or no impact on actually reducing the amount of fossil fuel generation that is required in the province’.

Noise was also a ‘big issue’ reported by participants. One participant described it as ‘the single most influential constraint in the decision process’. Some participants felt that low-frequency noise from turbines and the potential health effects were issues of concern to people living in proximity to modern wind turbines, e.g. in Pincher Creek.

This finding supports the results of a previous study done by Pedersen et al. (2007), where participants described noise from wind turbines as something that concerns them. On the other hand, some participants described the noise regulations and guidelines put in place by the regulatory commission as ‘harsh’ and ‘restrictive’.
Several participants also expressed concern about the potential cumulative effects of wind farm development, on wildlife and wildlife habitat, native prairie, and bats, birds and other species currently considered to be endangered. One participant said:

“We have had discussions about these impacts and the multiplier effects versus the footprint ... the likely ecological impact arising from the placement of wind..."
farms, the surface disturbance – from access roads and the turbines, the footprint on the ground, the vertical extension of the towers.’

However, a principal concern relating to land use was the potential for conflict with other land uses. One participant further illustrated this view:

‘We have to look at the multiple land uses, what the land uses are in a given area, and look at what their main concerns are and what their main issues are. We have to look at what the impacts are to the land owners, to the community or the county, etc.’

In addition, complex guidelines and setbacks on wind farm development were a consideration many of the participants expressed:

‘One of the biggest things for wind farm placement is having clear understanding of where there are constraints. And those constraints can be everything from impact on wildlife to understanding the level of development that is allowed in various areas, and how you can mitigate those constraints.’

The next recurring theme we found was the location of transmission infrastructure relative to wind farms. More than a third of the participants acknowledged that it was a major issue. For some of the participants, the convenience of integration was such a desirable feature that it overrode other concerns about land-use restrictions. In some cases, the lack of integration meant that plans for wind farm development were shelved:

‘There’s not a whole lot of transmission availability in the wind areas. So you really are restricted to finding a windy location that’s close to a transmission
line. And that’s why you see a lot of wind farms in Alberta aren’t going ahead because they can’t really get the transmission availability.’

2.4.4 Data requirements

In the interviews, the participants revealed a desire for more accurate and neutral information. The main reason for this, as cited by most of the participants, was the lack of standardized data collection procedures. This point was illustrated by this participant:

‘What tends to be missing, in terms of wind farms, is accurate data that deals with the issues. I can access publicly available studies, but what I don’t find – particularly in Alberta – is real-time, accurate information.’

Participants were particularly interested in having good-quality data, easy accessibility to the data and data that are collected through a clear process, with clearly defined criteria, within a specified period of time. One said:

‘I like to have scientifically verified data, not information on people’s personal blogs – people who have an opinion or vested interests. What is needed is information that is neutral, and a more structured approach of collecting information. This becomes particularly important when you are dealing with wildlife mortality and native grasslands.’

The results indicate that the decision process is mostly data-driven. A possible explanation is that stakeholders tend to explore data concerning the issues they identify with, indicating that they often source their data, and then use different software applications to analyse the data. In both the quantitative and the qualitative responses, most of the participants revealed that they
source their data mostly from private and government databases. However, obtaining these data turns out to be a more challenging task than expected due to the licence restrictions.

To access the data they need without paying exorbitant amounts, we found that stakeholders exchange data sets amongst themselves. For example:

‘A lot of us in the industry use the AbaData database for planning because it pools all of the layers together in one platform. However, it is not accessible to the public. But we have a license to it because they give us a license in return for access to our soils data.’

For most of the participants, the availability of accurate wind and weather data was a crucial component in the decision-making process. The data sets are usually accessed in real-time and historical streams. We found that it is common practice for stakeholders to set up meteorological stations where they can gather their own data. As one participant commented: ‘We actually have about 160 weather stations throughout the province. That information feeds into the database of some companies that do wind prospecting’.

A common response was the need to link the issues in context to the data. One participant stated: ‘We often find that the tools are misused because the correct context hasn’t been provided. And that leads to misinterpretation’. Tables 2.3 and 2.4 shows the established data sources and data layers used in the wind farm placement decision process.
### Table 2.3. List of data sources used for wind farm placement decisions in Alberta

<table>
<thead>
<tr>
<th>Data sources</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberta Electric System Operator (AESO) database</td>
<td>Open source</td>
</tr>
<tr>
<td>Alberta Sustainable Resource Development (AESRD) database</td>
<td>Open source</td>
</tr>
<tr>
<td>Alberta Environment</td>
<td>Open source</td>
</tr>
<tr>
<td>Statistics Canada</td>
<td>Open source</td>
</tr>
<tr>
<td>Environment Canada</td>
<td>Open source</td>
</tr>
<tr>
<td>Geodiscover Alberta</td>
<td>Open source</td>
</tr>
<tr>
<td>Applied Geomatics Sweden (AGS)</td>
<td>Commercial</td>
</tr>
<tr>
<td>Abadata</td>
<td>Commercial</td>
</tr>
<tr>
<td>Canadian Wind Energy Association (CanWEA)</td>
<td>Open source</td>
</tr>
<tr>
<td>AUC database</td>
<td>Restricted</td>
</tr>
<tr>
<td>Weatherdata.ca</td>
<td>Open source</td>
</tr>
<tr>
<td>Geobase</td>
<td>Open source</td>
</tr>
<tr>
<td>Natural Earth data</td>
<td>Open source</td>
</tr>
<tr>
<td>Data basin</td>
<td>Open source</td>
</tr>
<tr>
<td>United States Geological Service (USGS)</td>
<td>Commercial</td>
</tr>
<tr>
<td>Fish &amp; Wildlife Management Information (FWMIS)</td>
<td>Restricted</td>
</tr>
<tr>
<td>National Energy Board</td>
<td>Open source</td>
</tr>
<tr>
<td>Data.gc.ca</td>
<td>Open source</td>
</tr>
<tr>
<td>Google earth</td>
<td>Open source/commercial</td>
</tr>
<tr>
<td>National Oceanic &amp; Atmospheric Administration (NOAA)</td>
<td>Commercial</td>
</tr>
<tr>
<td>AltaLis</td>
<td>Commercial</td>
</tr>
<tr>
<td>Geogratis data</td>
<td>Open source</td>
</tr>
<tr>
<td>Land title information</td>
<td>Restricted</td>
</tr>
<tr>
<td>Alberta Energy Regulator (existing oil and gas facilities database)</td>
<td>Commercial/Restricted</td>
</tr>
<tr>
<td>Alberta Natural heritage information centre (ANHIC)</td>
<td>Open source</td>
</tr>
<tr>
<td>Air photo libraries</td>
<td>Open source/Commercial</td>
</tr>
<tr>
<td>Local municipalities mapping</td>
<td>Restricted</td>
</tr>
<tr>
<td>Local municipalities by laws</td>
<td>Commercial</td>
</tr>
<tr>
<td>Utility integration variable generation (UVIG)</td>
<td>Open source</td>
</tr>
<tr>
<td>Weather and Energy Prognoses (WEPROG)</td>
<td>Commercial</td>
</tr>
<tr>
<td>Supervisory control and data acquisition (SCADA)</td>
<td>Open source/Restricted</td>
</tr>
<tr>
<td>Grassland Vegetation Inventory (GVI)</td>
<td>Commercial</td>
</tr>
<tr>
<td>AWS Truewind</td>
<td>Commercial</td>
</tr>
<tr>
<td>Windserver</td>
<td>Commercial</td>
</tr>
<tr>
<td>Climate Viewer</td>
<td>Open source</td>
</tr>
</tbody>
</table>

In accordance with the Alberta regulatory codes and by laws guiding the placement of wind farms, participants often collected and analyzed data that were specific to the local terrain:
‘We also would look at spatial constraints, environmental features or infrastructure features in areas or towns, roads, rivers, rail, streams, lakes and environmental features like bird nests, historically resources, bird setbacks as well as any other environmental constraints that were specified in the regulatory codes.’

**Table 2.4. List of some data layers used for wind farm placement decisions in Alberta**

<table>
<thead>
<tr>
<th>Data layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prairie land cover</td>
</tr>
<tr>
<td>Drainage basins</td>
</tr>
<tr>
<td>Spatial constraints</td>
</tr>
<tr>
<td>Environmental features</td>
</tr>
<tr>
<td>Infrastructure (rail, roads etc.)</td>
</tr>
<tr>
<td>Natural features (rivers, streams, lakes, bird nests)</td>
</tr>
<tr>
<td>Setbacks</td>
</tr>
<tr>
<td>Heritage and historical resources</td>
</tr>
</tbody>
</table>

Judging from the participants’ responses, we were able to group the data used in the decision-making process into two main layers: base layer and constraint layer. The base layer provided general data (i.e. municipal boundaries, wind speed, topography and soil information). The constraint data contained information on the regulatory standards and existing land uses the wind farms may come in conflict with wind farms (i.e. wildlife, prairie land, vegetation, etc.).

We found that stakeholders often did not know what to do with the volume of data they collect. One of the participants said that they were ‘overwhelmed’ by the data coming in.
2.4.5 Task patterns

In the context of wind farm placement in Alberta, we define a task as any work activity that contributes directly or indirectly to the decision-making process. In analyzing the interview data, we focused on the pattern and types of tasks that the participants are usually engaged in in their line of work, given their involvement in wind farm placement issues.

The data in Table 2.5 suggest that planners tend to perform their work tasks alone or collaboratively. Often, there are several levels of interaction among different stakeholders in the decision process. Tasks are thus interdependent – i.e. tasks progress in such way that one thing leads to another.

Here, one participant, a regulatory official, explains the interdependent nature of the tasks:

‘The proponents provide us with information and when we meet them we can say, “Well, based on our information, here are some of the issues you are going to potentially find in this area”’.

Further, we found that the government regulators seem to prefer the manual approach, in which they make limited use of decision support tools in their line of work. For example, participants from the different regulatory agencies said they tend to conduct evaluations based on ‘prior knowledge and experience from seeing a lot of reports’, without consulting a structured checklist. One elaborated: ‘It’s kind of in our head. I guess from experience, you can say. We don’t have a checklist down but we know all the things to look for’.
<table>
<thead>
<tr>
<th>Task Categories</th>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>Search relevant databases for data</td>
</tr>
<tr>
<td></td>
<td>Review past decision reports on AUC website</td>
</tr>
<tr>
<td></td>
<td>Measure soil conditions</td>
</tr>
<tr>
<td></td>
<td>Extract data from government websites and databases</td>
</tr>
<tr>
<td></td>
<td>Research wind farm placement information online</td>
</tr>
<tr>
<td></td>
<td>Access information on native grasslands in Grassland Vegetation Inventory</td>
</tr>
<tr>
<td></td>
<td>Survey existing receptors or 'house locations'</td>
</tr>
<tr>
<td></td>
<td>Site visits</td>
</tr>
<tr>
<td></td>
<td>Correlate wind dataset for long term prediction</td>
</tr>
<tr>
<td></td>
<td>Integrate Wind production data</td>
</tr>
<tr>
<td>Analysis</td>
<td>Data analysis and reporting</td>
</tr>
<tr>
<td></td>
<td>Determine the proximity to roads and transportation infrastructure using cadastral map layers</td>
</tr>
<tr>
<td></td>
<td>Analyze land use for supporting infrastructures like irrigation canals</td>
</tr>
<tr>
<td></td>
<td>Analyze base information and meteorological data from weather stations and environmental databases in Alberta</td>
</tr>
<tr>
<td></td>
<td>Analyze AESO wind farm operational data</td>
</tr>
<tr>
<td></td>
<td>Wind resource modelling of proposed wind farm area</td>
</tr>
<tr>
<td></td>
<td>Analyze power output optimization</td>
</tr>
<tr>
<td></td>
<td>Analyze constraints</td>
</tr>
<tr>
<td></td>
<td>Calculate setbacks</td>
</tr>
<tr>
<td></td>
<td>Spatial analysis</td>
</tr>
<tr>
<td></td>
<td>‘Green field siting’ desktop analysis to identify suitable wind farm locations</td>
</tr>
<tr>
<td></td>
<td>Analyze archeological, CANVEC, and historical resource data</td>
</tr>
<tr>
<td></td>
<td>Measure and forecast wind flow resource of wind farm area</td>
</tr>
<tr>
<td></td>
<td>Perform calculations in excel</td>
</tr>
<tr>
<td></td>
<td>Analyze project lands for turbine placement and energy capture</td>
</tr>
<tr>
<td></td>
<td>Model noise output from turbine placement</td>
</tr>
<tr>
<td></td>
<td>Model noise output from surrounding infrastructure</td>
</tr>
<tr>
<td></td>
<td>Analyze constructability of the project</td>
</tr>
<tr>
<td></td>
<td>Analyze spatial constraints</td>
</tr>
<tr>
<td></td>
<td>Analyze environmental features</td>
</tr>
<tr>
<td></td>
<td>Analyze historical resources constraints</td>
</tr>
<tr>
<td></td>
<td>Develop spatial constraint mapping</td>
</tr>
<tr>
<td></td>
<td>Assess potential energy yield</td>
</tr>
<tr>
<td></td>
<td>Analyze shadow flicker set backs</td>
</tr>
<tr>
<td></td>
<td>Input uncertainties into the wind farm layout model</td>
</tr>
<tr>
<td></td>
<td>Map constraints</td>
</tr>
<tr>
<td></td>
<td>Analyze environmental studies, archeological studies, vegetation and wild life studies</td>
</tr>
<tr>
<td>Table 2.5. (Continued)</td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Design</strong></td>
<td></td>
</tr>
<tr>
<td>Design wind farm layout</td>
<td></td>
</tr>
<tr>
<td>Structure mapping tools around databases</td>
<td></td>
</tr>
<tr>
<td>Determine wind farm layout</td>
<td></td>
</tr>
<tr>
<td>Model wind flow for specific wind farm location</td>
<td></td>
</tr>
<tr>
<td>Use GIS to establish a constraint layer that limits the placement of wind farms</td>
<td></td>
</tr>
<tr>
<td>Optimize placement locations of wind turbines</td>
<td></td>
</tr>
<tr>
<td>Visualize wind flow models</td>
<td></td>
</tr>
<tr>
<td>Design photo simulations</td>
<td></td>
</tr>
<tr>
<td>Create 2D and 3D simulations</td>
<td></td>
</tr>
<tr>
<td>Perform wind farm layout design</td>
<td></td>
</tr>
<tr>
<td>Characterize vegetation and trees, surface roughness and water bodies</td>
<td></td>
</tr>
<tr>
<td>Design wind farm layout</td>
<td></td>
</tr>
<tr>
<td>Mapping and visualization</td>
<td></td>
</tr>
<tr>
<td>Develop visual simulation and photomontages</td>
<td></td>
</tr>
<tr>
<td><strong>Evaluation</strong></td>
<td></td>
</tr>
<tr>
<td>Evaluate data provided by applicants</td>
<td></td>
</tr>
<tr>
<td>Review content on environmental issues in submitted applications</td>
<td></td>
</tr>
<tr>
<td>Prepare sign offs for wind farm proponents as per mitigation guideline</td>
<td></td>
</tr>
<tr>
<td>Evaluate proposals submitted by proponents</td>
<td></td>
</tr>
<tr>
<td>Review content on wild life and wild life habitat issues in submitted applications</td>
<td></td>
</tr>
<tr>
<td>Advise proponents on pre-development survey</td>
<td></td>
</tr>
<tr>
<td>Review and research plan submitted by proponents</td>
<td></td>
</tr>
<tr>
<td>Determine mitigation and siting choices available to proponents</td>
<td></td>
</tr>
<tr>
<td>Develop and submit a review report on proposed project</td>
<td></td>
</tr>
<tr>
<td><strong>Feedback &amp; Reporting</strong></td>
<td></td>
</tr>
<tr>
<td>Request for further information from applicant</td>
<td></td>
</tr>
<tr>
<td>Advise clients on status of application</td>
<td></td>
</tr>
<tr>
<td>Quality control checks on collected data</td>
<td></td>
</tr>
<tr>
<td>Work with proponent to develop surveys</td>
<td></td>
</tr>
<tr>
<td>Generate wind resource report and other types of reports</td>
<td></td>
</tr>
<tr>
<td>Consult stakeholders</td>
<td></td>
</tr>
<tr>
<td>Obtain environmental permits</td>
<td></td>
</tr>
</tbody>
</table>

Certain comments seem to support the view that tasks done in preparing the wind farm applications are primarily geared towards fulfilling regulatory requirements and maximising wind capture. Typically, developers work to establish a constraint layer and wind flow potential in areas where they want to site the wind turbines. One of the participants explained the process:
'In a typical process we will first look at the project lands and how to inject the right number of turbines to maximize energy from the site. Then we will run specific noise modelling to make sure we satisfy the sound constraints for the project site. We also would look at spatial constraints, environmental features or infrastructure features in areas or towns, roads, rivers, rail, streams, lakes and environmental features like bird nests, and so on.'

The most common task performed by the participants we interviewed was research. Participants often searched for information about wind farm development projects. These information-search tasks were mostly restricted to publicly available data, as one participant, a land owner, explained: ‘So what I would usually do, when I am looking into the whole wind farm thing, is to look at available studies that address the impact that wind farms have on the environment’.

Our findings also indicate that different groups of stakeholders tend to do similar work tasks in the decision process. For example, regulators were more involved in the review and negotiation tasks and developers tend to do more analytical tasks, while consultants are more involved in the design tasks. Based on the data, we identified the tasks that are performed in the decision process and grouped them into five different categories (see Table 2.5).

On further review of the task categories, we found that the stakeholders were firmly grounded in the pattern of tasks. Combining these tasks, we were able to trace the dependencies created by each category of tasks. Each category of tasks can be seen as a different stage in the decision process. For example, the tasks in the research category are more like data-gathering tasks and are often the starting point in the decision-making process. These tasks are generated
for the purpose of gathering information on the basis of which crucial decisions are made. Information gathered in the research category is used in performing the analytical tasks. The analytical tasks constitute the bulk of work done in the decision process. The analytical tasks are both qualitative and quantitative in nature, and set the stage for the design tasks. The design tasks are used to determine overall feasibility of the project and require a lot of expertise. These tasks are usually performed by consultants with a variety of software tools, as this participant explained: ‘When we try to design the layout of a wind farm we use consultants. So we don’t directly design the layout’.

Collaboration is a key aspect in both the evaluation and reporting tasks. It is at this stage that actual decisions are taken. The tasks for a specific project can revert to any of the previous stages depending on the decisions made by the evaluators. One participant gave an overview of the tasks at this stage: ‘We review their [the proponent’s] plan, and, using the research they have done, determine what mitigation is available to them, what siting choices they have – one that allows the least amount of impact’.

Based on our analysis of the task categories, we developed a structure that shows the relationships amongst and the sequence of the task categories (Figure 2.2).

**Figure 2.2. Sequence of tasks for wind farm placement decisions in Alberta**

As illustrated in Figure 2.2, it is clear that the tasks are interdependent and follow a sequential order. Each task category is fully supported by unique data sets. It is reasonable to
suggest that most of the tasks can be performed on a computer-based platform. Other tasks that require field visits can also be simulated on a computer modelling system.

2.4.6 Existing tools

At present, stakeholders use different tools to support different tasks at different stages in the decision process. One participant said: ‘There are lots of different software packages we use, and I would say that they all satisfy different purposes’.

We also found consensus among participants that existing decision support tools are generic systems, and not specifically designed for local needs. Some participants cited less-than-satisfactory experiences with the purchase and use of decision support tools which were not designed for the local situation. Three participants reported varying levels of difficulty using generic tools:

‘I actually don’t like it [geographic information systems (GIS) tool]. I don’t find it intuitive. I find that the latest version really decreased my functional permit. I find that the editing stuff is clunky. I have been discouraged in the past about the proprietary data formats, and the ability to share data across platforms.’

Another stated:

‘I’d say that some of the functionality of ArcGIS is buried so you have to hunt a little bit, and there a lot of different tools and extensions. It’s a big package with a lot of capability, but it gets expensive very quickly.’

And:
‘Windpro is not intuitive. There are a few different steps to it, but the steps all make sense when you start using it. But initially it is a bit of hard software to learn’.

Based on the study data, we identified different functionalities that existing generic tools perform in the decision-making process. Table 2.6 shows the functionalities that stakeholders currently derive from existing tools based on their responses. Some of the participants suggested that the existing decision support tools were more often used as a means of getting planning approvals rather than for determining ideal locations for wind farm placement. In addition to this, most of the tools were static, e.g. photomontages, and could not be used for data analysis. Rather, they are used mainly as a public relation tools.

From the interviews, we found that any of the tools can be used to support stakeholders and decision makers in a variety of tasks leading to the final placement decisions. According to the participants, many of these general tools had the capability to incorporate the data and analytical functions required in the decision-making processes.

However, what tended to be missing was a ‘balanced approach in the design of the models embedded in the tools’. According to one participant:

‘I feel like the models themselves, the outputs, were good in the sense that they were intuitive. But in most cases, the focus of these tools was either to assist the wind farm development potential or to focus on environmental considerations which will make wind farm development less advisable.’
Table 2.6. Summary of existing tools and functions

<table>
<thead>
<tr>
<th>Tools</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCI Geomatica</td>
<td>For modeling and analyzing base features and infrastructure e.g. roads, rails, house locations, noise, surface vegetation</td>
</tr>
<tr>
<td>Mathematica</td>
<td></td>
</tr>
<tr>
<td>Google earth</td>
<td></td>
</tr>
<tr>
<td>Global mapper</td>
<td></td>
</tr>
<tr>
<td>CadnaA</td>
<td></td>
</tr>
<tr>
<td>WindFarmer</td>
<td>For modeling and predicting the wind energy yield</td>
</tr>
<tr>
<td>WindFarm</td>
<td></td>
</tr>
<tr>
<td>Wasp</td>
<td></td>
</tr>
<tr>
<td>Mobile office Initiative (IMOD)</td>
<td>For preliminary feasibility assessment</td>
</tr>
<tr>
<td>Opengo</td>
<td></td>
</tr>
<tr>
<td>Quantum GIS</td>
<td></td>
</tr>
<tr>
<td>GIS</td>
<td></td>
</tr>
<tr>
<td>Openfoam</td>
<td>For designing the wind farm layout</td>
</tr>
<tr>
<td>Mathematica</td>
<td>For designing buildable area</td>
</tr>
<tr>
<td>Matlab</td>
<td></td>
</tr>
<tr>
<td>Openwind</td>
<td></td>
</tr>
<tr>
<td>Grant management system (GMS)</td>
<td>Used as spatial databases</td>
</tr>
<tr>
<td>FWMIS</td>
<td>For document handling</td>
</tr>
<tr>
<td>Windserver</td>
<td></td>
</tr>
<tr>
<td>WindFarmer</td>
<td></td>
</tr>
<tr>
<td>Weatherdata.ca</td>
<td></td>
</tr>
<tr>
<td>Meteodyn</td>
<td></td>
</tr>
<tr>
<td>Fluent</td>
<td>For modeling wind flow and wind speed data</td>
</tr>
<tr>
<td>Windographer</td>
<td></td>
</tr>
<tr>
<td>Windpro</td>
<td></td>
</tr>
<tr>
<td>Windserver</td>
<td></td>
</tr>
<tr>
<td>Photomontages</td>
<td>For stakeholder consultation</td>
</tr>
<tr>
<td>StakeTracker</td>
<td></td>
</tr>
<tr>
<td>Photosimulation</td>
<td></td>
</tr>
<tr>
<td>SustaiNET</td>
<td></td>
</tr>
<tr>
<td>Weprog</td>
<td></td>
</tr>
<tr>
<td>Conservation offsets</td>
<td></td>
</tr>
<tr>
<td>Landscape Analysis Tool</td>
<td>For soil analysis and conservation planning</td>
</tr>
<tr>
<td>Alberta soils information viewer</td>
<td></td>
</tr>
<tr>
<td>Alberta Climate Viewer</td>
<td></td>
</tr>
<tr>
<td>Landscape Analysis Tool</td>
<td></td>
</tr>
<tr>
<td>Grassland vegetation inventory</td>
<td></td>
</tr>
<tr>
<td>Wildlife sensitivity layers</td>
<td></td>
</tr>
<tr>
<td>Habitat Suitability Model Search Tool (HSI)</td>
<td></td>
</tr>
<tr>
<td>WindFarmer</td>
<td>For assessing environmental impact</td>
</tr>
<tr>
<td>AUC websites</td>
<td>For desktop research.</td>
</tr>
<tr>
<td>Online search engines and databases</td>
<td></td>
</tr>
<tr>
<td>Alberta Environment</td>
<td></td>
</tr>
<tr>
<td>Environment Canada</td>
<td></td>
</tr>
<tr>
<td>Opengeo</td>
<td></td>
</tr>
<tr>
<td>GIS cadastral layers</td>
<td></td>
</tr>
</tbody>
</table>
As mentioned before, some of the participants, specifically the government regulators who evaluate all of the wind farm planning applications, make limited use of decision support tools in their line of work.

For most, the unavailability of specific tools that support their work proved an obstacle too difficult to surmount. One said: ‘At this point, not really. We looked at using some GIS for our work but, because the tool is not readily available and it doesn’t really help us, most of our stuff is done manually’.

Most participants shared the view that visualization was a useful attribute in all the tools and software identified. A number of participants described the additional functionalities they would like to see in a wind farm placement decision support tool.

Phrases like ‘what I would like’ and ‘what would be useful’ were echoed in several comments. For example:

‘What would be really useful is a portable tool which combines the wind data with ability to import other constraints in real time’.

And:

‘What I envision is something that can be connected to GPS [a geographic positioning system], something you can access easily on your mobile device, something that is flexible and can easily import different layers using real-time data, e.g. wind data, transmission lines.’

Another said:
‘I like the notion of maps as a kind of a consensus-building instrument. So, you know, I may be able to twiddle some knobs or pull some levers or whatever, parameterize the model so that it spits out an output that reflects my values.’

And finally:

‘I would like to have the application on a mobile phone. I would like to be able to access the data on a mobile phone. I always try to think from the point of view of farmers, and they say that 90% of farmers have smartphones. Why shouldn’t they be able to access the data on an app on their smartphones?’

In sum, the participants indicated a common preference for the following:

- Tools with ‘interactive mapping capabilities’.
- Tools that ‘allow data import from different sources’.
- Tools that ‘have good visualization component’.
- Tools which can allow them to ‘create their own codes and functionalities’.
- Tools that can provide an ‘analytical and cross-functional’ platform’.
- Tools that have capabilities for ‘a lot of technical design work’.
- Tools that are ‘not skewed to a certain type of decision outcomes’.
- Tools that are ‘built on an open source platform’.
- Tools that are ‘easy to use’ and ‘do not have a steep learning curve’.
- Tools that allow ‘project optimization and impact assessment analyses’.
- Tools with the capability to ‘analyze options and trade-offs’.
2.4.7 Usability requirements

To identify the common usability features that stakeholders may prefer, we probed the participants for information about the common devices (specifically laptop, personal computer and smartphone) and common software tools (apps) they use often. We measured the participants’ preferences in two ways: via the questionnaire and through qualitative analysis of the interviews. Table 2.7 shows the frequency distribution of the preferred workstation devices as indicated by the participants.

Table 2.7. Percentage distribution of preferred device (n=15)

<table>
<thead>
<tr>
<th>Device</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desktop PC</td>
<td>28.1</td>
</tr>
<tr>
<td>Laptop</td>
<td>34.4</td>
</tr>
<tr>
<td>Smartphone</td>
<td>25.0</td>
</tr>
<tr>
<td>Tablet</td>
<td>12.5</td>
</tr>
</tbody>
</table>

*NOTE: All percentages are based on responses by 15 participants.

On reviewing the data, it became apparent that laptops and desktop computers were perceived as the preferred devices, with about 34% and 28% of participants citing them as the most frequently used devices. Smartphones and tablets followed closely, at 25% and 12.5% respectively. We found that the pattern of choice is evenly distributed amongst desktop PC, laptop and smartphone, and the participants were more likely to alternate amongst any of the devices depending on their location and work tasks. These findings suggest that the proposed tool has to be interoperable across different platforms and devices.

Interestingly, almost all of the participants reported a tendency to use five software tools—email app, calendar, Excel, Google Maps and weather apps – in the devices we identified. Just as
interestingly, we were able to identify the usability features in these apps that the participants liked. This participant had this to say about a weather app:

‘I just like the fact that it is easy. You can just touch it, and it goes. Same with reading the news, you can just touch what you need to see and swipe it. I like the simple functionality’.

Table 2.8. Summary of useful apps and usability features

<table>
<thead>
<tr>
<th>Frequently used apps</th>
<th>Useful usability features</th>
<th>User experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excel</td>
<td>Data analysis capability</td>
<td>Ease of Use</td>
</tr>
<tr>
<td></td>
<td>Report generation capability</td>
<td>Familiarity</td>
</tr>
<tr>
<td></td>
<td>Can create Simple visualizations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Document handling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Database capacity</td>
<td></td>
</tr>
<tr>
<td>Outlook email app</td>
<td>Ability to sync across platforms</td>
<td>Portability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ease of Use</td>
</tr>
<tr>
<td>Calendar app</td>
<td>Simple, clean Layout</td>
<td>Flexibility</td>
</tr>
<tr>
<td></td>
<td>Interoperability across devices</td>
<td>Simplicity of use</td>
</tr>
<tr>
<td>Google maps</td>
<td>Interactive map interface</td>
<td>Convenience</td>
</tr>
<tr>
<td></td>
<td>Interoperability in different devices</td>
<td>Easy accessibility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Versatility</td>
</tr>
<tr>
<td>Weather apps</td>
<td>Real-time data analysis</td>
<td>Easy access</td>
</tr>
<tr>
<td></td>
<td>Interactive Visualizations</td>
<td>Simple functionality</td>
</tr>
</tbody>
</table>

Table 2.8 shows the frequently used software applications and useful usability features that we collated based on the participants’ responses. A particular theme that emerged was that the five apps we identified can be used for planning and decision support applications. Hence, it is reasonable to suggest that the usability features in these software applications, as stated by the participants, should be incorporated into the design of the proposed decision support tool.
It should be noted that the contextual nature of stakeholders’ requirements, as identified in this study, makes an effective case for designing tools that are adapted to the Alberta domain. In the next section, we discuss the results, connections and themes that would help focus the design on desirable functionalities of the proposed tool.

2.5 Discussion and Implications for Design

The results from the study highlight stakeholder requirements that could perhaps lead to more effective decision support when planning the placement of wind farms in Alberta. We outline below the important design implications that arise therefrom.

2.5.1 Design to support stakeholder personas in the decision process

One of the most difficult challenges for tool designers is to place themselves in the shoes of the end-users (Jankowski et al. 2006). Too often, the designer’s experiences and ideas are far removed from those of the users, and interfaces that appear user friendly to the designer are not perceived as useful by the end-users. This study created the opportunity to characterise the personas that represents the needs of groups of stakeholders who are the target users of the proposed decision support tool.

From the demographic and interview data, we identified realistic information on behaviour patterns, goals, values, scenarios, skills and motivations that embodied the stakeholders involved in the wind farm placement decision process in Alberta. We applied segmentation strategies to determine stakeholder preferences and to classify them accordingly. This process allowed us to empathize with the stakeholders and their experience, thus providing key insights on how to support them better in their decision tasks. A particular view that emerged from this study was that the stakeholders, irrespective of their affiliations, are involved in making decisions about the
placement of wind farms. In analysing the above, we found that stakeholders had clear motivation to seek information and to support their decision-making with the use of decision support tools. However, this motivation was driven by different goals and attitudes. Given the diversity of personas identified in the study, we recommend a focus on designing features that can integrate the needs of stakeholder personas in the decision process. Design efforts can thus be prioritized based on the personas. For instance, the results suggest that a visual-based system can provide a useful platform for all the different stakeholders.

Furthermore, the high reported rate of computer and internet usage suggest that stakeholders would be comfortable interacting with a web-based decision support system. These features – visual-based, computerized, interoperable and web-based – represent the high-priority needs of stakeholder personas identified in the study, and can thus form a realistic basis for design. In addition, the design prototype can be evaluated against the personas and their needs.

2.5.2 Design analytical models to incorporate key decision issues

Participants in the study reported a variety of information on the issues surrounding wind farm placement planning in Alberta. In addition, we found that stakeholders’ background knowledge tends to influence their perception of issues. Information needs varied with the level of expertise, and with background and interests. The results indicate that the issues and concerns have some influence on the decision thinking of the study participants. This suggests that stakeholders are more likely to search for information that aligns with their interests and knowledge of the issues.

In order to support their decision-making, information relevant to these issues should be incorporated in the decision support tool to allow the stakeholders to evaluate potential impacts.
of wind farm placement locations and alternative decision outcomes. We acknowledge, however, that it is difficult to capture and illustrate human knowledge in computer algorithms. Hence, we suggest the use of interactive, analytical models, as a back-end component, to link the issues with the data sources. We recommend that the model design should be implemented in an integrated manner to effectively support the information analysis of different stakeholders with different or cross-linked interests.

The importance of this integration is evidenced in the responses from the stakeholders who participated in the study, whose interests are sometimes similar or varied depending on the issues at stake. In addition, we suggest that the models should be capable of supporting information analysis relating to the specific issues we identified in this study. For example, this requirement can be applied when modelling the noise impacts and noise setback constraints. Inputs to this model may include historical and real-time data variables on land use patterns, noise constraints, visual setbacks, environmental assessments, etc. Given the divergence of views on issues as projected by stakeholders, we recommend that a trade-off analysis model should be incorporated into the tool, to enable different decision makers to explore trade-offs in the decision-making process.

The overall output of the models should reflect a balanced analysis and should be specific to wind farm development in Alberta.

2.5.3 Devise strategies for incorporating domain data

The study revealed that most of the data used in the decision-making process are unique to the areas where wind farms are likely to be located in Alberta. Clearly, therefore, specific tailoring of the decision support to the Alberta domain is needed. Further evidence suggested that
data retrieval, through research, is usually the beginning of a complex decision-making process. Improperly sorted or irrelevant data could result in flawed decisions. The results also revealed that some of the data have proprietary restrictions, which again restricts the ability of the general public to access information.

Consistent with this view is the implication that stakeholders have to expend considerable effort in obtaining the information they need. This becomes a major impediment when designing a decision support tool, because, as one of the participants stated, ‘the main thing people are interested is in the data’. Given these findings, the database system should have the capability to incorporate a variety of open data sources that are not restricted by licenses. From the interviews, we found that data are usually requested for analytical purposes. Accordingly, we recommend the tool have an analytical modelling system where data from different sources can be processed. Since stakeholders are already adept at using their own data, we suggest the user interface and modelling system should have a modular capability that allows different users to plug in and analyze their own data. This approach was discussed by Cheng et al. (1998) and more recently by Chamberlain et al. (2012).

2.5.4 Design interfaces to improve performance on tasks

Judging from the interviews, it is reasonable to argue that the tasks performed by stakeholders should be taken into consideration when designing a decision support tool. The interview data opened new insights into the complex, semi-structured, sequential and interdependent nature of the tasks involved in wind farm placement decisions in Alberta. After identifying the tasks, determining the task frequency and matching the task activities to different categories, it was clear that the tasks contribute to the process and outcome of wind farm
placement decisions. The findings show that the majority of the tasks are currently performed with different types of computer software tools. We also discovered that some of the participants did not use any kind of computerized tools, relying more on their residual knowledge. In both cases, the evidence supports the view that a decision support technology can improve their overall efficiency in completing the tasks.

Further analysis of the tasks uncovered the different variables involved in the decision process. For instance, we found that the decision process involves several phases of interaction between different stakeholders. This would require the proposed tool to be able to support independent and collaborative work whenever appropriate. In addition, the results show that different capabilities will be required to support different categories of tasks at different levels in the decision process. In other words, the proposed tool should be designed to support analysis, research, evaluation, design and reporting tasks. Given the level of computer usage reported in the quantitative data as a gauge, we can infer that stakeholders are comfortable with using computers and the internet to perform their work tasks. This reinforces the need to implement the proposed decision support tool on a computer-based platform.

The results also suggest that most of the tasks are data-driven, such that stakeholders conscientiously look for data resources required to accomplish their tasks. We suggest that the data should be structured according to the task flows in the model and user interface design. With this approach, we anticipate that stakeholders will able to perform more tasks in a shorter period of time.
2.5.5 *Design to support interactive visualization and analysis*

As reported earlier, stakeholders use a variety of generic tools to support their tasks at different stages in the decision process. We have learned about the functionalities available through the tools we identified. While the existing tools have their uses, the interview data show that participants cannot always find the capabilities they require to perform their work tasks in a single tool. As a result, stakeholders use several tools to perform their tasks. Data analysis also revealed a shared acknowledgement of the generic nature of the existing tools. Most of the tools had been designed for other purposes and were being adapted to the wind farm placement domain. Many of the participants reported the challenges they had when interacting with the different tools. They indicated that the existing tools were not easy to use. This evidence further supports the case for a place-specific tool for the Alberta terrain. Importantly, interactive report generation and documenting capabilities were also highlighted as useful aids to data analysis.

The goal here would be to automate what is currently a manual, paper process. Further analysis uncovered a recurring component in all the tools – that of visualization. Participants provided insightful comments on how the visualization capabilities in the existing tools provide a gateway into the complex data. Thus, it becomes obvious that incorporating a visualization component in the proposed decision support tool may increase the likelihood of adoption and stakeholder acceptance.

2.5.6 *Design to enhance usability and user experience*

The data on user experience was particularly relevant because it helped us to identify and prioritize usability features that stakeholders share in common. For some of the stakeholders, the emphasis was on ease of use, or lack of it, in existing tools. Based on the results, we recommend
designing the proposed tool in ways that will simplify usability and improve user experience. Functionalities such as data analysis capability, portability, ease of use, visual analysis capability, simplicity and interoperability were the most consistent features that participants reported as useful in both desktop and mobile applications. Table 8 shows the common usability features and shared preferences.

These findings are consistent with the rest of the study. Ideally, the proposed decision support tool will be effective if these usability features are incorporated into the design. We suggest that the reported usability features should be the basis for selecting the interaction style that would best suit the stakeholders. In particular, we recommend that these features should be used as evaluation benchmarks during the development of the proposed tool.

In summary, these requirements suggest that the proposed tool should be designed with a visual and analytical focus. We propose a basic modular design that would allow new modules to be added and removed easily without major surgery on the entire system.

To satisfy these conditions, we recommend that the proposed tool should be designed with the following core attributes:

- A database component that is able to retrieve and store real-time, historical and simulated data from a variety of sources – the database component should be designed in a modular fashion such that it can be linked to different models;
- A back-end analytical component that consists of a set of interactive and interlinked models that are coupled to the database component and can run analysis and generate reports using available data; and,
A front-end visualization component consisting of an interactive user interface that can display output from the analytical component. Further, the user interface should be implemented on an adaptive, web-based, interoperable platform, such that it can be easily accessed by all stakeholders involved in the decision process, using multiple devices like computers, mobile phones and tablets.

2.6 Contributions

This study demonstrates the usefulness of mixed research methods in providing an in-depth understanding of the issues related to wind farm placement decisions. The study extends current knowledge by bringing together for the first time the decision support requirements of different stakeholders involved in planning the placement of wind farms in Alberta. This is one of the primary contributions in this work.

Significant design implications arise from the study findings. First, we created realistic personas of stakeholders that can serve as design tools. Second, we found that background knowledge was an important factor in designing tools that will be useful to stakeholders. Results from the study also helped to identify the nature of tasks that currently go into the wind farm placement decision process. The implication is that we can design the tools to support the tasks. Further, the findings established a strong linkage between the data requirements and issues that relate to wind farm placement planning.

While data requirements for decision support tools have been considered in other domains, no research has been conducted on the specific database requirements for wind farm placement
decision support in Alberta. Our study discovered new insights into how stakeholders in Alberta might use the proposed tool in the decision process.

These findings will provide a conceptual design framework that takes into account the interdependent, semi-structured and collaborative nature of the decision process. Taking these insights together, we have derived a set of recommendations for a decision support tool that can be seamlessly integrated into the wind farm placement decision process in Alberta.

Although this study is concerned with the placement of wind farms in Alberta, the results and design implications may be extended to other decision support domains that have complex data, diverse stakeholders’ interests and semi-structured tasks.

2.7 Limitations

We acknowledge that our familiarity, assumptions and experiences with the Alberta setting may have affected how we framed the study and interpreted the results. Nevertheless, we tried to address this potential bias by collecting data via two different methods – qualitative and quantitative – and from different stakeholders across the wind energy industry in Alberta. In reporting the results, we let our participants speak through quotations, such as those highlighted in this chapter.

Although we interviewed a modest sample of 15 stakeholders, individually they represent significant sectors of the stakeholder population. Our participants hold important positions in the stakeholder groups to which they belong, and they tend to speak on behalf of their groups. For example, we interviewed a land owner who was nominated by a land owners’ association. Thus, we consider our study sample to be fairly representative of the target population.
In reporting the findings, we had to make decisions about what was more important and less important in the data. We hope that our use of qualitative, inductive data analysis approach helped organize the textual data to provide accurate and reliable interpretations.

As a validity check, we discussed our preliminary findings with other researchers involved in similar research. However, we are confident the validity of our findings can be assessed using other qualitative analysis techniques, with similar results.

Finally, the list of design recommendations is not exhaustive and may not cover all aspects of decision support for wind farm placement in the study area. However, the design recommendations are reliable because they are based solely on evidence gathered in the course of this study.

2.8 Future work

In future work, it may be useful to identify and include more stakeholder groups involved in planning the placement of wind farms in the study area. This may enrich the perspectives and results obtained from the study.

Future studies, using other qualitative data analysis procedures, may consider using inter-rater ratings to strengthen the reliability of data analysis agreement.

We plan to design and implement a prototype to demonstrate the design recommendations from this study. The prototype will give a broad view of the proposed tool, with capabilities for interactive visual representations that can harness the human abilities to discern patterns in data. We will evaluate the prototype in a focus group where stakeholder’s feedback will be gathered.
2.9 Summary

The study reported in this chapter elicited a wealth of information on the range of issues concerning wind farm placement and the decision support needs of stakeholders in Alberta. There were a number of noteworthy findings. What can be seen from these findings is the correlation between the issues and decision support needs of stakeholders. Further, to be effective, the findings indicate that the proposed decision support tool has to embed functionalities that are easy to use, can support the decision process, integrate seamlessly into stakeholders’ work tasks and can support data analysis.

Taking these insights together, we developed a list of recommendations that focus the design choices on the stakeholders’ requirements. The design recommendations are innovative because they adhere closely to evidence gathered from real stakeholders in the course of this study. From this perspective, the findings demonstrate the usefulness of eliciting stakeholder needs when delivering effective decision support tools for the placement of wind farms in Alberta.

References


Abstract

There is currently an increasing effort to develop visual analytics (VA) tools that can support human analytical reasoning and decision-making. In the last decade, advances in this field has allowed the application of various kinds of VA systems in real-world settings. While this represents a promising start from a product design perspective, part of the challenge to the research community is that current VA tools have evolved without due consideration of standardized design criteria and processes. Accordingly, some questions remain to be addressed on what are the useful, underlying attributes of effective VA tools and how their impact can be measured in human-product interaction. These considerations indicate a need to identify a specific range of VA tools and assess their capabilities through state-of-the-art empirical analysis. To address these issues, we conducted a systematic review of 470 VA papers published between 2006 and 2012. We report on the bibliometric techniques, the evaluation attributes and the metrics that were used to sample and analyze the body of literature. The analysis focused mainly on 26 papers that implemented visual analytics decision support tools. The results are presented in the form of six inductively derived design recommendations that, when taken together, uniquely contribute to the fields of product design and visual analytics.

3.1 Introduction

We currently witness a growing interest of product design research in the field of visual analytics. Defined as the science of analytical reasoning facilitated by interactive visual interfaces (Thomas and Cook 2006), visual analytics tools have been heralded as technology products that can synthesize information from complex and dynamic data and in ways that directly
support assessment, planning, and decision-making. The earliest work relating to real world
application of visual analytics can be linked to Bilgic (2006) and Chen et al. (2006). Recent
advances, for example (Andrienko et al. 2007; Rudolph et al. 2009; Savikhin et al. 2011; Reddy
et al. 2012; Booshehrian et al. 2012), show that application of VA tools can facilitate decision-
making in real-world settings.

While a broad range of VA tools exists, evidence regarding their effectiveness, and
experience of use, is rather limited. This has stimulated a shift of focus from the extent and
manner in which visual analytics can be applied in real-world settings, to understanding the
design process and the underlying attributes of effective visual analytics, and how the quality of
the product experience is evaluated through the use of performance metrics.

Alben (1996) defined the human-product interaction “experience” to include all the aspects
of how people use an interactive product: the way it feels in their hands, how well they
understand how it works, how they feel about it while they are using it, how well it serves their
purposes, and how well it fits into the entire context in which they are using it. If these
experiences are successful and engaging, then the tools become valuable to users and noteworthy
of the design and evaluation process from which they emerged.

Although considerable research has focused on the design and evaluation of VA tools (Jeong
et al. 2008; Plaisant et al. 2008; Konecni et al. 2010; Chinchor et al. 2012; Kang and Stasko
2012; Kluse et al. 2012), the outcome is a research agenda characterized by a host of experiential
concepts that, to some extent, differ in terms of theoretical backgrounds, research directions, and
design processes.

From a product design perspective, design evaluation requires the consideration of several
performance attributes rather than common usability metrics (Liu et al., 2011). These factors
clearly illustrate the need to develop a general framework that can facilitate the design and evaluation of VA tools. With qualitative and quantifiable measures, researchers can adequately evaluate a product's capabilities in relation to its use (Burnell, et al., 1991). Hassenzahl & Tractinsky (2006) argue that such assessments have an impact on future user experiences. Moreover, they form a basis for the research community to streamline the design process in a manner that reflects the goal of enhancing user experience.

These considerations motivated us to articulate a model that can be used for design and evaluation of VA tools. Using the evaluation metrics proposed by Scholtz (2006a), and Wang et al., (2011) as a priori framework, we conducted a systematic review that seeks to evaluate, synthesize, and present the empirical findings in visual analytics literature from 2006 to 2012. The review focuses mainly on papers that implemented visual analytics decision support tools (VADS), and provide an overview of application areas, their attributes, and design implications for research and product development.

In doing so, we hope to uncover findings that can be extrapolated broadly to contribute to a common understanding of approaches and practical guidance for designing VA tools.

The chapter is organized as follows: In “Background” section, we provide a discussion of user experience evaluation as a feature of product design in visual analytics. “Methods” section describes the methods and the theoretical roots taken to derive the evaluation framework used for this review. “Results” section reports the findings of the review. “Discussion” section discusses the findings in the form of six inductively derived recommendations. “Limitations” and “Future work” sections reports on the limitations, contributions, and concludes with recommendations for further research.
3.2 Background

3.2.1 User experience in the product development context

The discussion of user experience in product design research draws on some interesting insights. Hassenzahl (2005) suggests that a product, into which we classify visual analytics systems, has certain attributes which can be combined to convey a peculiar character. In order to trigger an experience of a product, a designer has to manipulate these attributes to give access to utility and usability. The same can also apply to the overall quality of a product which, as articulated by Hassenzahl & Tractinsky (2006), often depends on how well the attributes are linked with users’ needs. Clearly, these reflections highlight the complex and layered nature of product experience, and point to a need to use certain attributes to design products that can be effective and useful.

3.2.2 User experience metrics for visual analytic tools

Researchers have long argued that usability metrics are inadequate for evaluating the effectiveness of intelligent technologies such as visual analytics tools (Despont-Gros et al. 2005; Scholtz 2006b; MacDonald 2012; Tintarev and Masthoff 2012). Scholtz (2006a) and Wang et al., (2011) proposed an evaluation framework for visual analytics tools that goes beyond standard usability metrics. The framework proposed by the authors includes focusing on performance attributes such as situation awareness, collaboration, interaction, creativity, and utility. Within this framework, they recommended specific metrics to provide designers with measures to track how the design components support the user experience.

According to Tullis & Albert (2008), user experience metrics, that are based on a reliable system of measurement, can add structure to the design and evaluation process, give insight into the findings, and provide value to users. In other words, the user experience metrics can help
identify “good” VA tools from “not so good” VA tools by showing, for instance, if a analyst’s experience on using VA tool is improved or not.

With these considerations in mind, our research questions for this study are then as follows:

1. What is the nature of visual analytics product application in decision support settings?

2. What attributes and metrics are needed to enhance the human-product interaction experience in visual analytics decision support tools?

3.3 Methods

Guided by the established method of systematic review (Higgins and Green 2008), we undertook the review in six distinct stages: a search for relevant papers, development of a coding protocol, identifying the inclusion and exclusion criteria, data extraction, critical analysis of data, and synthesis of findings. In this section, we describe the methods used.

3.3.1 Data sources

The review spans the period from 2006 to 2012, following the peer-reviewed papers published since Illuminating the Path (Thomas and Cook 2005). Specifically, we obtained the initial set of papers from the electronic databases of journals and conference proceedings that are known to publish VA papers, namely: VAST, Information Visualization, EUROVA, Pacific Viz, and IEEE Lecture notes in Visual analytics.

This was followed by a manual search of online search engines for additional VA papers published in other journals and conferences. This procedure yielded a total dataset of 470 VA publications. The list is not exhaustive, but the major VA research strands are represented. We then organized and indexed the papers for sampling.
3.3.2 Inclusion and exclusion criteria

We chose decision support in visual analytics because it provides a concrete application sample for the analytical experience. We also considered it important to define the selection criteria for our final sample, because we wanted to reduce the possibility of selection bias. The final sample was selected using the following criteria:

- Papers must be published in a peer-reviewed journal or conference proceedings;
- Papers must be full papers with empirical evidence (contest papers, workshop briefs, panel sessions, posters, and short papers were excluded);
- Papers must implement a VA technology for decision support in a real-world setting.

To this end, we performed a manual check on the abstracts of the 470 papers using the inclusion criteria. In addition, we read the text of each paper to verify its ‘decision support’ content. Most of the VA papers identified in the initial search, that clearly did not meet the criteria, were omitted from further consideration. Following this procedure, we collated a final sample of 26 papers which we found to be of acceptable rigor, credibility, and relevance (Table 3.2).

3.3.3 Coding protocol

We developed a coding protocol using the Cochrane Handbook style for Systematic Reviews of Intervention (Higgins and Green 2008) and the content analysis technique of a priori coding (Stemler 2001). The coding protocol was mostly influenced by the evaluation framework proposed by Scholtz (2006), and Wang et al., (2011). From their work, we developed six high level attributes: Situation awareness, Collaboration, Interaction, Creativity, Utility and User-oriented design. All six attributes are distinguished in having their own underlying metrics,
which we adapted as coding units in the coding protocol. We describe the attributes and coding units below.

3.3.3.1 Situation awareness

Situation awareness (SA) is a cognitive process in decision-making and is defined as ‘the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future’ (Endsley 1995).

According to the visual analytics research agenda (Thomas and Cook 2006), the analytical process involves similar tasks such as: understanding historical and current situations, as well as the events leading to current conditions; identifying possible alternative future scenarios; determining indicators of the intent of an action; and supporting the decision maker in times of crisis. VADS tools that do not support situation awareness tend to allow information overload or inadequate information to affect decision-making.

For this attribute, we wanted to measure how situation awareness is incorporated in the design of VADS tools. We developed the coding units according to the three layers of Endsley’s situation awareness model, which are: perception, comprehension, and projection (Endsley 1995). For the perception layer, we reviewed the papers to determine the extent to which the VA decision support tools show a demonstrated ability to track the changes of information when operated by the users in field trials. For the comprehension layer, we assessed the application of VA decision support decision support tools in providing contextual analysis of environments to users. For the projection layer, we searched the literature for test reports on the aptitude of
VADS to support future scenario projections. And finally, we wanted to understand how many of the tools were reported to have a combination of the three afore-mentioned layers.

3.3.3.2 Collaboration

The ability to share data while using different views is a necessary feature of visual analytics systems that are designed for collaboration (Scholtz 2006a). Analysis of this attribute was guided by the need to review the effectiveness of VA decision support systems, as reported in the literature, when facilitating communication and information sharing between users. For this purpose, we iteratively developed the following coding units: ability to share evidence; supports intuitive communication; can allow multiple, coordinated views; can track information flows; and combination of all four metrics.

3.3.3.3 Interaction

Assessment of this attribute was based, in part, on the ISO 9241-110 principles of human-system interaction (ISO 9241-110 2006). We consider this interaction as a form of “dialogue” between the human component and the VA system. We examined the papers in respect to whether, and to what extent, the VA decision support tools were able to support interaction with users. To this end, we coded the data using the following units: suitability for the task; controllability; self-descriptiveness; support customization of information; enable access to information; and combination of all five metrics.

3.3.3.4 Creativity

Lubart & Geogsdottir (2004) defined the concept of creativity as the ability to produce work that is high in quality and appropriate (i.e., solves problems, useful for certain tasks). We share this view of creativity because it suggests that creativity can occur in complex domains where
decisions are made. This implies that support for creativity should take into account the environment that supports decision-making.

As such, VADS tools that support creativity should be able to enhance the creative ability of the user(s), therefore improving the analytical processes and outcomes. To evaluate this attribute, we reviewed the literature using the following metrics as coding units: support individual tasks; effective in searching for analytical results; ability to show high quality of analytic solutions; user satisfaction with solutions; and combination of all four metrics.

3.3.3.5 Utility

According to Scholtz (2006), the utility of the VA system is one of the most important metrics of measuring its effectiveness from the user perspective. We developed the coding units based on Davis’s technology acceptance models (TAM) (Davis, 1985), which examines psychometric properties of the systems’ characteristics as perceived by the users.

In essence, the environment should allow the user to spend more time on task and less time on the system being used. Compatibility with the context of use, perceived ease of use, perceived usefulness, increased effectiveness on the task, and less aggregate time expended in finding analytical solutions, are factors that can be associated with the utility attribute of visual analytic decision support tools. We evaluated the utility attribute using the afore-mentioned metrics as coding units.

3.3.3.6 User-centred design

‘User-centred’ design methods have been widely discussed within product design discourse, and also in the disciplines of human computer interaction (HCI), human factors engineering and
ergonomics (Chamberlain and Bowen 2006). McDonagh-Philp (1998) suggests the following definition of user-centred design:

"User-centred design is a design methodology that utilises the target product users as a designing resource to increase the understanding of the design practitioner."

This definition influenced the development of the coding scheme along the lines of the visual analytics research agenda put forward by Thomas and Cook (Thomas and Cook 2006). In formulating the coding units, we sought to measure the extent to which designers of VA decision support tools focus on the intended users, real data sets, and real tasks. We also wanted to understand how the user requirements are defined in the design and development life cycle of VADS. In the light of these considerations, we developed the following coding units: analysis of user and context requirements; active involvement of intended users; iteration of usability design; evaluation with intended users; multi-disciplinary design input; use of real-world data; and combination of all units.

3.3.4 Procedure

First, we tested the coding protocol on a random selection of five papers from the sample dataset. Two independent raters—two PhD students in computer sciences—joined us in this process. At the end of this phase, we modified some coding units to account for discrepancies in the protocol.

We then coded the sample dataset independently and discussed the results during intensive team meeting sessions, over a period of eight months. These discussions provided a platform for validity checks, consistency in the coding, resolving disagreements, and strengthening the intra-
coder and inter-coder reliability. The time taken to code each article varied considerably, ranging from over four hours to an hour.

To maintain consistency, we re-read the papers on which the coding protocol was based. Using Cohen’s Kappa (Cohen 1960), we calculated the inter-rater reliability to be 0.64, which can be considered a “substantial agreement”. Further, we discussed our preliminary findings with colleagues who also conduct research in information visualization and visual analytics. At the end of this procedure, we resolved all disagreements and analyzed the data.

3.4 Results

3.4.1 Overview of VA publications and application areas

Table 3.1 shows the distribution of the papers by journal and conference proceedings from the search results. The substantial number of identified papers (n = 470) suggests that visual analytics is a rapidly growing research field. Overall, we found that 5.5% of VA papers published between 2006 and 2012 developed decision support applications for real world problems. This suggests that limited research work has been done in terms of the design and application of VADS to real world decision support problems.
Further analysis was based on the final sample of 26 papers. This sample reflects the 22 different applications of visual analytics for decision support in real world settings (see Table 3.2).

<table>
<thead>
<tr>
<th>Journal</th>
<th>Year</th>
<th>VA papers (2006-2012)</th>
<th>VADS papers (2006-2012)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAST</td>
<td>2012</td>
<td>62</td>
<td>__</td>
<td>__</td>
</tr>
<tr>
<td>VAST</td>
<td>2011</td>
<td>57</td>
<td>3</td>
<td>5.3</td>
</tr>
<tr>
<td>VAST</td>
<td>2010</td>
<td>58</td>
<td>1</td>
<td>1.7</td>
</tr>
<tr>
<td>VAST</td>
<td>2009</td>
<td>56</td>
<td>5</td>
<td>8.9</td>
</tr>
<tr>
<td>VAST</td>
<td>2008</td>
<td>46</td>
<td>2</td>
<td>4.3</td>
</tr>
<tr>
<td>VAST</td>
<td>2007</td>
<td>46</td>
<td>5</td>
<td>10.9</td>
</tr>
<tr>
<td>VAST</td>
<td>2006</td>
<td>23</td>
<td>3</td>
<td>13.0</td>
</tr>
<tr>
<td>EURO VA</td>
<td>2012</td>
<td>7</td>
<td>1</td>
<td>14.3</td>
</tr>
<tr>
<td>EURO VA</td>
<td>2011</td>
<td>10</td>
<td>__</td>
<td>__</td>
</tr>
<tr>
<td>EURO VA</td>
<td>2010</td>
<td>10</td>
<td>__</td>
<td>__</td>
</tr>
<tr>
<td>Others</td>
<td>2006-2012</td>
<td>88</td>
<td>6</td>
<td>6.8</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>470</td>
<td>26</td>
<td>5.5</td>
</tr>
</tbody>
</table>
Given the data in Table 3.2, we can infer that most of the application areas have spatial and temporal aspects; and often involved stakeholders in the time-critical decision-making processes. The data shows that the diversity of applications areas correlates with the research agenda for visual analytics.
Table 3.3. Frequency distribution of attributes reported in VADS tools (2006-2012)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Coding references</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Situation Awareness (N=52)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can track changes in information</td>
<td>19</td>
<td>(36.5)</td>
</tr>
<tr>
<td>Can provide environment for contextual analysis</td>
<td>25</td>
<td>(48.1)</td>
</tr>
<tr>
<td>Can support future scenario projections</td>
<td>4</td>
<td>(7.7)</td>
</tr>
<tr>
<td>Combination of all</td>
<td>4</td>
<td>(7.7)</td>
</tr>
<tr>
<td><strong>Collaboration (N=63)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to share evidence</td>
<td>3</td>
<td>(4.7)</td>
</tr>
<tr>
<td>Can support intuitive communication</td>
<td>12</td>
<td>(19.1)</td>
</tr>
<tr>
<td>Can allow multiple, coordinated views</td>
<td>36</td>
<td>(57.1)</td>
</tr>
<tr>
<td>Can track information flows</td>
<td>12</td>
<td>(19.1)</td>
</tr>
<tr>
<td>Combination of all</td>
<td>0</td>
<td>(0)</td>
</tr>
<tr>
<td><strong>Interaction (N=124)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suitability for the task</td>
<td>12</td>
<td>(9.7)</td>
</tr>
<tr>
<td>Controllability</td>
<td>39</td>
<td>(31.5)</td>
</tr>
<tr>
<td>Self-descriptiveness</td>
<td>12</td>
<td>(9.7)</td>
</tr>
<tr>
<td>Support customization of information</td>
<td>35</td>
<td>(28.2)</td>
</tr>
<tr>
<td>Enable access to information</td>
<td>21</td>
<td>(16.9)</td>
</tr>
<tr>
<td>Combination of all</td>
<td>5</td>
<td>(4.0)</td>
</tr>
<tr>
<td><strong>Creativity (N =137)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Support individual tasks</td>
<td>11</td>
<td>(8.0)</td>
</tr>
<tr>
<td>Effective in searching analytical results</td>
<td>58</td>
<td>(42.3)</td>
</tr>
<tr>
<td>Ability to show high quality of analytic solutions</td>
<td>46</td>
<td>(33.6)</td>
</tr>
<tr>
<td>User satisfaction with solutions</td>
<td>13</td>
<td>(9.5)</td>
</tr>
<tr>
<td>Combination of all</td>
<td>9</td>
<td>(6.6)</td>
</tr>
<tr>
<td><strong>Utility (N=51)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived ease of use</td>
<td>4</td>
<td>(7.8)</td>
</tr>
<tr>
<td>Compatible with the context of use</td>
<td>14</td>
<td>(27.5)</td>
</tr>
<tr>
<td>Perceived usefulness</td>
<td>11</td>
<td>(21.6)</td>
</tr>
<tr>
<td>Enhances effectiveness on the task</td>
<td>10</td>
<td>(19.6)</td>
</tr>
<tr>
<td>Reduction in time</td>
<td>4</td>
<td>(7.8)</td>
</tr>
<tr>
<td>Combination of all</td>
<td>8</td>
<td>(15.7)</td>
</tr>
<tr>
<td><strong>User-centred design (N=175)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analysis of user and context of use</td>
<td>80</td>
<td>(45.7)</td>
</tr>
<tr>
<td>Active involvement of intended users</td>
<td>22</td>
<td>(12.6)</td>
</tr>
<tr>
<td>Iterative design</td>
<td>17</td>
<td>(9.7)</td>
</tr>
<tr>
<td>Evaluation with intended users</td>
<td>17</td>
<td>(9.7)</td>
</tr>
<tr>
<td>Multidisciplinary design input</td>
<td>7</td>
<td>(4)</td>
</tr>
<tr>
<td>Use of real world data</td>
<td>32</td>
<td>(18.3)</td>
</tr>
<tr>
<td>Combination of all</td>
<td>0</td>
<td>(0)</td>
</tr>
</tbody>
</table>
However, it also reinforces the need to develop more applications for decision support in other real-life scenarios where complex information has to be processed and analyzed.

Table 3.3 shows the attributes of VADS in the reviewed papers as reported by the coding protocol. Each code refers to frequency and percentage values of the coding units as identified in the data.

3.4.2 Situation awareness

We observed that perception (i.e., ability to track the changes of information—36.5%) and comprehension (ability to provide environment for contextual analysis—48.1%) were predominant features in the final sample of papers we reviewed. However, we found few examples (7.7%) where situation awareness was linked to the ability of the systems to support users in making future scenario projections. The assessments also indicate that the three levels were fully integrated in about 7.7% of the sample papers.

Additionally, we found several examples where references were made on the capability of the VADS tools to support situation awareness. For example, some of the references read as follows:

... the planner should also be able to spot and explore rationality problems when time permits but immediate detection is not so much required...

... the planner should involve his/her background knowledge and/or additional information to assess the feasibility of this plan...
... as the user inserts decisions points, scrolls through time, and revisits other scenarios, these interactions are tracked and displayed in the decision history view...

Further, there were instances where the SA attribute was clearly demonstrated in the papers, notably:

...the visual framework allowed managers to ask new questions, promoted discussion and debate, and built trust between managers and scientists for the data analysis process...

...He (the analyst) observed that the system’s ability to process large datasets allows him to quickly filter the data into manageable subsets while providing interactive spatiotemporal displays that further aid him in making a decision using the best information available...

From the references, it can be seen that situation awareness is a factor in the design of VADS tools. It gives an indication of how the VADS systems are designed to incorporate the user’s background perceptual knowledge when performing analytical tasks; how their comprehension of the situation was improved following interaction with the VA tool; and, consequently, the level of future projections derived by the users.

3.4.3 Collaboration

The data indicate that 57.1% of VADS tools can allow multiple, coordinated views. In facilitating intuitive communication, we observed that the incorporation of contextual data and domain knowledge in VADS tools made it easier access information (19.1%). We also recorded
19.1% codes where the capability of VADS tools to track the flow of information was demonstrated. This suggests a link between the capability of existing VADS tools to actively track the visual changes in a system and allowing users to explore the visual representations interactively. For example, one document expressed, ‘These different modes enable multipurpose use of the display. One of the purposes is detection of potential feasibility problems due to simultaneous arrival of multiple vehicles to the same place.’

Relatedly, an interesting aspect of the data was the low frequency we recorded for the VA systems’ ability to facilitate evidence-sharing among collaborators. We also observed that there was hardly any paper that reported all the metrics we coded for this attribute.

### 3.4.4 Interaction

Table 3.3 shows the distribution of the codes for Interaction. Roughly two-thirds of the codes were more or less direct references to Controllability and Customization of information. Based on this evidence, we can deduce that technical functionality and visual elements were a central consideration in the VADS design process.

The other 4 coding units reported low frequencies (the exception was ‘access to information’, which had 16.9%). This suggests that information used for analysis and decision-making was usually explored at various levels of detail. When we reviewed the papers in terms of Suitability for the task and Self-descriptiveness, we found a striking similarity in frequency (9.7%). According to ISO 9241-110, self-descriptiveness relates to system consistency, quick comprehension, and clarity of possible actions from the user perspective. On the other hand, interaction enhances a tool’s suitability for a task if the user can efficiently complete a task.
From the foregoing, we can infer that the extent to which self-descriptiveness is incorporated in a VADS tool appears to have a direct correlation on its suitability for the task—at least when viewed in the context of the tool’s interaction capabilities. We interpreted this to mean that self-descriptive interactions in VA systems are more likely to support users in carrying out their tasks effectively.

3.4.5 Creativity

With respect to creativity, the results indicate that most of the VADS tools in the papers we reviewed were considered to be effective in supporting high quality of analytical outcomes on the visual interfaces. Further, the coded references appear to show a trend of user satisfaction with solutions and the extent to which the VADS were able to support individual tasks. A possible reason for this may be that evaluation experiments were actually tested for this feature, and so the user’s comments were often recorded. The relevance of creativity on the user satisfaction can be measured with the frequency we recorded (9.5 and 6.6% respectively). Table 3.3 illustrates this further.

We also found some references in which users reported their creative experiences with VADS tools, for example:

...User comments indicated that data-taking facilitated decision-making.

...the planner concludes that the capacities in the destination places are not optimally used.

...the response of these policy makers was highly positive, verifying that the goal of facilitating communication... was well achieved.
3.4.6 Utility

Table 3.3 displays the results for the attributes pertaining to Utility. Overall, 27.5% codes we measured for this attribute were in the context of use. We surmise that this relates to the level of inquiry into the user requirements by VA researchers—that is, the degree to which they ensure the tools are applicable to the context.

The results also highlight favorable numbers for Perceived usefulness, which, as defined by Davis (1989), is the degree to which a person believes that using a particular system would enhance their performance on a task. Interestingly, the systems are reported to enhance effectiveness on the task, showing a strong co-relation with Perceived Usefulness. The results tend to support the view that the two attributes are interdependent.

We also found a strong correlation between perceived ease of use and time expended in finding analytical solutions, judging from the exact frequencies of the codes. We deduce that Perceived ease-of-use of VADS tools may be a significant determinant of the amount of time spent on finding analytical solutions. The evidence also suggests that the amount of time gained by the use of VADS tools is not being tracked in evaluation experiments.

Regarding the extent to which the VA applications incorporated all these coding units, the data show a statistically significant trend, which suggests that some of the papers attempted to elicit information from the users on how their experiences had been impacted by interaction with the VADS tools. Specifically, the users commented on the adequacy of the designs to their work tasks, thereby increasing their ability to make informed decisions. However, these were found in only about one third of the sample papers reviewed.
3.4.7 User-centred design

We found many references of user-oriented design in the sample papers. This appears to support the view that most VADS researchers collaborate with users at some point in the design process (Damodaran 1996). The difference between the various approaches, we observed, is the degree of user influence in the design process. In this case, the degree of user influence was informed by both the type and depth of user participation.

The distribution in Table 3.3 indicates that the context of use and users’ decision support needs were explored and analyzed in detail by VA researchers prior to the tool design. This trend was consistent in all the papers we reviewed. One interpretation is that VADS largely involve the application of technology to novel decision-making tasks that have not been researched by other disciplines.

Further analysis of the references indicates that only 12.6% of the papers reflect an active involvement of users in the design processes. We believe that this phenomenon highlights a growing need in the development of VA decision support tools that are designed for real world applications.

The reason is that many real-world decisions, even when they seem to focus on technical issues, are in fact sociotechnical in nature (Damodaran 1996), thus requiring a more active involvement of the users to provide specifications in the design process.

A noteworthy feature in the chart is the similarity in the results we recorded for Iterative Design and Evaluation with intended users. We observed that the process of evaluation, in which changes and refinements are made, did not often involve users. Remarkably, this trend was reported in only about 9.7% of the papers. For a process that is intended to improve the usability and effectiveness of a design, the implication is that the current distribution may not sufficient.
According to Thomas & Cook (2005), to build an effective VADS requires collaboration from multiple disciplines. Thus, it can be argued that inadequate collaborative participation in the design of VA systems makes the process time-consuming and error-prone. The results also show that multidisciplinary design input needs to be emphasized in the design VADS tools. This suggests a gap between researchers, programmers, designers and users, in contrast to the guidelines proposed in the VA research agenda.

We also observed that only 18.3% of papers reported the use of real-world data in VADS. This may imply that majority of the papers use simulated datasets to design the systems. This underlines the key issue of product validity and credibility in VA decision support tools.

3.5 Discussion

There are several possible ways of looking at these findings, but we will focus only on six aspects in this discussion. The recommendations, as stated below, are not prescriptive. Rather, they reflect suggestions to help improve the product design approach of VA tools, specifically VADS tools.

First, the results imply a limited emphasis on the incorporation of Situation Awareness as a key attribute in the design of VA decision support tools. The application of visual analytics to decision support requires a much more advanced level of situation understanding and accurate projection of future events in view of the user’s analytic tasks. With such tasks, the user is uncertain about the nature of the problem, the alternative solutions or value for making a choice (Alavi and Napier 1984). It may be useful if future VADS are designed to adequately support the users overall awareness of issues when evaluating complex information. Situation awareness forms the critical input to an individual’s decision-making, and is often the basis for all
subsequent actions (Endsley 1988). Therefore, we recommend that VA decision support systems should be designed to facilitate the continuous acquirement of Situation Awareness, by providing solutions to domain-specific and time-critical problems. Design techniques should be developed to enhance situation awareness, and, to objectively assess the effect of the VADS tool on a user’s situation awareness.

The ability to support evidence-sharing, synchronously and asynchronously, among collaborative users, in a VA system is important. While we gained further understanding on the trend of Collaboration in VA literature, we found that no single study incorporated all the units we used in measuring the attribute. A possible reason is that typical design processes reflect a focus on the ability of the VADS technology to capture and track the steps taken by the users in the process of decision-making. This attribute is useful in the analysis process, but often, as the results show, not enough to support evidence-sharing among collaborative users of the VADS tool. The data provide ample justification to support this view. To facilitate effective communication and information sharing between collaborators, we recommend that VA decision support tools should purposively incorporate all the attributes that support seamless collaboration between users. At a minimum, VADS tools should demonstrate the capability:

- To share data between users;
- To support intuitive communication;
- To support multiple, linked displays that would allow different users to assess different data;
- To track information flows between users.

We recommend that these attributes should be targeted in the design and evaluation stages of VA decision support tools.
We can look at Interaction as a communication process between the user and the system (Bennett 1976). In a successful interaction process the user interacts automatically with the system while concentrating on the analysis at hand. What we infer from the results is the tendency of interaction dialog in existing VADS tools to be geared towards controllability and customization. While the data indicate that interaction dialogs allows users sufficient access to information, the evidence tend to suggest a trend in which the dialogs were often less comprehensible to the users in ways that made VA tools rather unsuitable for the analytic tasks. This is perhaps a clear indication of what Green et al. (2011) refers to as the general disposition to create interfaces based on their own methodologies and interaction metaphors. Clearly, this mismatch underlines the need for interaction design techniques that are user-adapted and context-oriented. This type of design requires a focus on the outcomes of the interaction rather than the process of interaction. We propose an adaptive model in which components such as, the context of use, the user, the VA system, and the designer combine to establish products and outcomes that respond adequately to the six attributes we used in measuring interaction.

As noted earlier, Creativity may be stimulated or hindered depending on the nature of the environment in which a task is performed. The relative frequency we observed in the literature may be a reflection of how visual analytics enables user creativity in multiple domains. At these levels, one can assume that current VA tools can support faster and more accurate decision-making. Therefore, more work needs to done to stimulate creativity. Thus, a VADS environment should allow for elements that are inclined to support the user’s creative needs. In addition, we recommend that VADS tools should be designed in such a way that the interface can act as a vehicle of creativity and self-expression for the decision maker.
The purpose of most decision support tools is to support the user in arriving at a decision through analysis. For VADS tools, we associate this goal with the notion of Utility, which can be measured through feedback from the user. The results show a tendency of VADS tools’ designers to take the contextual aspects into consideration. However, this development does not always translate to ease of use and less time spent on tasks. The evidence presented in Table 3.3 suggests that the relationships between the Utility attributes are similar.

Specifically, one can see that ease of use influences the amount of time spent on task. The findings have implications on user acceptance. Rather than focusing only on usability issues, we suggest that designers should also evaluate and adapt the systems for usefulness, timeliness, and ease of use.

With respect to User-centred design, our findings identified a typical approach in VADS tools, which is—build a prototype, test with intended users, measure usability criteria, and iteratively refine design. However, in a user-oriented approach, it is important to determine the user and context requirements prior to design. In addition, seeking multidisciplinary input in the implementation stages could allow higher levels of adoption by users. Also from the sample papers, we deduced that the data used in the design process were mostly simulated data, and therefore may not portray an accurate dynamics of decision problems that require the use of VA tools. This calls for the use of real datasets in the design and development cycle.

3.6 Limitations

Some limitations may have affected the data collection and interpretation of results in this review. First, due to the diverse publication venues available to VA researchers, extracting all the papers in the field would have been difficult. There is also a risk that relevant papers may have
been omitted due to our choice of keywords and search strings. However, we are confident that the initial dataset of 470 papers sufficiently represents the major VA publications from 2006 to 2012, and that this number is large enough to support the validity of our conclusions.

Second, we appreciate that systematic literature reviews and content analysis methodologies are mostly subjective. However, the rigor of the coding technique used and the research experience of the researchers ensured that the data analysis was fairly reliable. We believe that other researchers using the same coding protocol would produce similar results.

We acknowledge that difficulties arise when attempting to investigate textual data for ‘state-of-the-art trends’. We are aware that generalizability of these analyses is limited by the focal sample employed for the study. In this paper, we analyzed only 26 papers that are specific to decision support. This, in itself, sheds a limited light into the published literature. The metrics we adapted into coding units were considered with great attention to allow, as much as possible, an accurate analysis of the data.

The models and literature we used to support the metrics were selected based on our research questions and objectives. Nevertheless, we acknowledge that there may be other models and metrics out there. It is not our intention to present the framework we used as a well specified theory. Rather, we invite further research, using other models and attributes.

The content analysis approach posed some methodological challenges: the selection procedure for including the papers was somewhat subjective; also, due to the extensive logistics and time constraints, we could not extend the interrater and intra-rater agreement to include more researchers. In future reviews, it may be beneficial to expand the number of researchers working on the coding procedure, which may in turn increase the reliability of inferences made from the data.
Finally, in the course of conducting this research, we have developed a deeper appreciation of the passion, commitment, creativity, and rigor brought to the field of visual analytics by the thousands of dedicated researchers. We recognize the diversity of perspectives on visual analytics and related research. For these reasons, we do not suggest that the findings are indicative of the general trends in the field, but rather some trends that reflect our specific research questions, methodological assumptions, and research interests.

3.7 Future work

So far, the design attributes and metrics proposed here have not been tested in real world settings with visual analytics tools. We will continue to refine these attributes through additional projects and to apply them to the design evaluation of a VA decision support tool with stakeholders in a real world domain.

3.8 Summary and Contributions

This chapter reviewed the most exciting aspects of product design and development in the field of visual analytics. In this paper, we provided a rich description of an evaluation framework that is, in part, already studied in visual analytics research, but not well considered in the design and evaluation of visual analytics tools. To our knowledge, this is the first comprehensive review to address the benefits of integrating VA tools in product design. The results indicated a general consensus that visual analytics tools have the potential to support analytical reasoning in many fields of human endeavour. It also provided preliminary data to better understand the reach and capabilities of visual analytics decision support tools in real-world applications.

The results have several implications for designers of VA tools: first, the findings answer the question ‘What attributes and metrics are needed to enhance the human-product interaction
experience in visual analytics decision support tools?’ This is one of the primary contributions from this study. Further, the findings suggests that using the attributes and metrics identified in this study could result in comparable outcomes in the design and evaluation of VA tools.

Third, while the design evaluation approach demonstrated here is specific to visual analytics, the user experience attributes and metrics we described can be adapted to any type of product design and any type of technology. This is one of the contributions from this study.

In conclusion, the findings gave rise to new design recommendations for VA decision support tools. These design recommendations were constructed from the analysis of the data sample. We expect that the proposed design recommendations will uniquely contribute to the fields of visual analytics, product design and user experience design.

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Abstract

Incorporating the requirements of stakeholders may result in better tools to support decision-making for wind farm placement planning in Alberta. However, translating the requirements into design concepts has been identified as an important implementation issue. Another challenge concerns the lack of innovative strategies on which to base the implementation process. To this end, we present the design and development of a web-based Alberta Wind Decision support tool (AB–WINDEC) prototype. The purpose of the tool is to support wind energy stakeholders in identifying potential placement locations for wind farms in Alberta. The development of the prototype involved three steps: first was the specification of decision support requirements drawn from stakeholders. Based on these requirements a framework was established to lay out the structure, scope, and concepts for the tool development. Following this, the prototype was designed and implemented using iterative prototyping techniques. These approaches are grounded in principles and methods from human-centered design research, experience design, product design, and visual analytics. The resulting prototype offers useful functionalities such as data integration and management, task support, interactive analytics, and thematic visualizations.

4.1 Introduction

Decision support tools have been defined as computer technology solutions with capabilities to support complex decision-making in many areas of human endeavour (Shim et al. 2002). A number of researchers have highlighted the primary role they play in improving the abilities of individuals and groups to manage information, clarify preferences and present the trade-offs involved in multiple, alternative choices (Keeney 2004; Kockelman et al. 2008). In recent times,
new types of decision support tools have evolved to help stakeholders analyze key issues that affect land use planning processes (Ramírez-Rosado et al. 2008; Simão et al. 2009; Lejeune et al. 2010; Cathcart 2011; McKeown et al. 2011; Ouammi et al. 2012).

Despite the promise of decision support tools, numerous barriers restrict their application in processes that involve stakeholders with different backgrounds, different interests, and different levels of expertise and experience with using computer-based tools (McIntosh et al. 2005). At present, decision-making processes associated with wind farm placement planning in Alberta fall within this category. In the study done in chapter 2, some practical issues that limit the acceptance and integration of decision support tools in the decision processes were identified. These include: inconsistent and incomplete datasets, and usability problems arising from poor design and non-adaptability of existing tools to the local context and to the information needs of stakeholders (Adagha et al. 2015a).

These limitations arise partly due to the lack of design methodologies guiding the development of decision support tools (Bardos et al., 2001; Sànchez-Marrè et al., 2008; Stockton et al., 2012). Furthermore, prior tool development projects within the areas of unstructured and semi-structured problems, such as wind farm placement planning, have not been explored to a level where socio-technical frameworks are used to address the combined requirements of technologies, stakeholders and decision processes.

To address these limitations, recent research has advocated the need to develop attributes and guidelines that can facilitate the development of effective decision support tools (Adagha et al. 2015 b; Miah, Kerr, and Hellens 2014). The premise is that a decision support tool should be capable of fulfilling its intended functions if the right approach is used in developing it (Rip and Kemp 1998).
In the light of the foregoing, there is now growing recognition that focused design approaches can help deliver effective decision support tools in domains such as wind farm placement planning (Fedra, 1995; Poch et al., 2004). We take the view that understanding the decision support requirements, translating them into concrete design concepts, and applying innovative design techniques may lead to successful implementation of effective decision support tools for wind farm placement planning in Alberta.

In this chapter, we describe the techniques we used in designing and implementing the AB–WINDEC prototype. First, we present a summary of the stakeholders’ requirements for a wind farm placement decision support tool in Alberta. In the next section, we present the socio-technical framework that lays out the specifications and dimensions for the proof-of-concept prototype. Further, we describe the methods used in conceptualizing and implementing the prototype design. The prototype’s content and functionality, as delivered, is also discussed. We conclude the chapter with a brief discussion of the design considerations and the ideas for future work.

4.2 Design materials and methods

4.2.1 Specification of decision support requirements

The process of identifying requirements is generally considered an important step in tool development (Maguire 2001). Chapter 2 provided some findings on decision support requirements for wind farms placement planning in Alberta. The interpretation of these findings, into design concepts and specifications, is discussed in this section.
4.2.1.1 Stakeholder personas

Stakeholder personas are qualitative representations of people we want to be able to support. Specific stakeholders’ personas were provided to help the design team understand stakeholder’s perspectives and the level knowledge that goes into the decision process, and also to impress upon the design team that stakeholders are not the same as they appear. The key stakeholder personas identified in chapter 2 were: conservation, climate change, and community groups; developers; landowners; consultants; planning and regulatory officials. These stakeholder personas require the following attributes in a decision support tool:

a. visual-analytics interface
b. suited to the local terrain
c. computerized
d. interoperability across various devices and platforms
e. web-based

4.2.1.2 Analytical models to incorporate key decision issues

In Chapter 2, it was also established that the information needs of stakeholders in Alberta were mostly influenced by their background knowledge and interests. This finding also gave rise to the following requirements:

a. Interactive, analytical models that are designed as back-end components to link the key issues with the data sources.
b. Analytical models should be integrated to effectively support different stakeholders with different or cross-linked interests.
c. Inputs to the models should include historical and real-time data.
d. A capability to analyze and communicate the trade-offs between different alternatives and simultaneously allow stakeholders to explore how their preferences influence the decision outcomes.

4.2.1.3 Support data management

Data requirements from chapter 2 shows several areas of common interest including:

a. A data management system where Alberta-specific open source data, from different sources, can be integrated in real-time.

b. A capability to input data relevant to the decision process and have those data stored in a database system.

c. A responsive data input facility that connects the database system to the analytical models.

d. A user interface that allows different stakeholders to plug-in and analyze their own data.

e. A model that can support analysis of data and generate reports accordingly.

4.2.1.4 Support stakeholders in performing decision tasks

Findings from Chapter 2 also revealed the nature and sequence of tasks that go into wind farm placement decisions as predominantly research tasks, analytical tasks, design tasks, evaluation tasks, and reporting tasks. These gave rise to the following requirements:

a. The interface of the proposed tool should be tailored to support different categories of tasks, and at different levels in the wind farm placement decision process.

b. The proposed tool should be able to support independent and collaborative work.

c. Structure the data with the concurrent task flows in the model and user interface.
d. The proposed decision support tool should be implemented on a computer-based platform.

4.2.1.5 Support interactive visualization and analysis

Chapter 2 outlined the following requirements to support data exploration in the decision support tool:

a. Visual and analytical capabilities.

b. Interactive visualization capabilities.

We associate these requirements with the concept of visual analytics, see (Thomas and Cook 2006), in which interactive data visualizations are used to support analytical reasoning.

4.2.1.6 Enhance usability and experience of use

Chapter 2 also proposed the following requirements to enhance usability and experience of using the proposed tool:

a. Ease of use.

b. Ability to support visual data analysis.

c. Web-based platform.

d. Interoperability across multiple devices.

e. A modular interface layout.

4.2.2 Design requirements

Based on the decision support requirements discussed above, we interpreted the following design specifications:

- Develop a data manager that can support analysis of historical and real-time data.
- Design a front-end visualization component consisting of an interactive interface that can display output from the analytical component.
- Design a back-end component that consists of interactive and inter-linked analytical models that can generate visualizations from data.
- Implement the tool on a web-based, interoperable, platform.
- Adapt the interface design, its content and workflow tasks, to specific stakeholder personas.

4.3 A Socio-technical framework for Alberta wind decision support tool (AB-WINDEC)

A conceptual framework can be used to identify and structure the relationships between all the constituent parts of a decision support system (Sprague 1980). For this reason, we developed a conceptual socio-technical framework to integrate the decision support requirements of wind energy stakeholders, and to guide the design and implementation of a decision support tool that fits these requirements.

The framework was based on the findings of a study conducted by Adagha et al. (2015a). Insight from the study helped to conceptualize the six aspects of wind farm placement decision support process in Alberta. These are reflected in the framework as, context of application, decision issues, stakeholder personas, purpose of the tool, decision support requirements, and intended outcomes (see Table 4.1).

Integrating the social needs of stakeholders with practical technology requirements subscribes to the socio-technical approach to technology design (Scacchi 2004; Whitworth and Ahmad 2012). This approach is similar to what is obtained in software requirements engineering (Aurum and Wohlin 2003).
<table>
<thead>
<tr>
<th><strong>Context of application</strong></th>
<th>Wind farm placement planning decisions in Alberta</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose of the tool</strong></td>
<td>To support stakeholders in identifying appropriate placement locations for wind farms in Alberta</td>
</tr>
</tbody>
</table>
| **Decision issues**       | Preserve high value ecological assets  
|                           | Existing land use and wind farms  
|                           | Wildlife protection  
|                           | Noise  
|                           | Ice throws  
|                           | Shadow flicker  
|                           | Visual aesthetics  
|                           | Wind availability  
|                           | Access to transmission |
| **Stakeholder personas**  | Consultants  
|                           | Developers  
|                           | Researchers  
|                           | Regulators  
|                           | Civil society groups  
|                           | Landowners |
| **Decision support requirements** | Web-based and computer-based tool  
|                                 | Provide task support functionalities  
|                                 | Analytical capability powered by data-driven models  
|                                 | Visualization capability powered by data analysis models  
|                                 | Interoperability across different platforms, browsers, and devices  
|                                 | Data integration capability to feed analytical models  
|                                 | Facilitate data integration  
|                                 | Facilitate research  
|                                 | Enable data analysis  
|                                 | Enable design of wind farm layout |
Table 4.1 (Continued)

<table>
<thead>
<tr>
<th>Enable electronic evaluation of reports and applications</th>
<th>Intended outcomes of the tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allow electronic reporting and feedback on submitted applications</td>
<td>Enhance stakeholders situation awareness and knowledge of issues</td>
</tr>
<tr>
<td>Enable impact assessment</td>
<td>Generate analytical solutions</td>
</tr>
<tr>
<td>Enable evaluation of options</td>
<td>Reduce time spend on tasks</td>
</tr>
<tr>
<td>Enable trade-off analysis</td>
<td>Facilitate quicker and more accurate decisions</td>
</tr>
<tr>
<td>Can operate on an open-source platform</td>
<td>Facilitate trade-offs analysis</td>
</tr>
<tr>
<td></td>
<td>Facilitate evaluation of placement applications</td>
</tr>
<tr>
<td></td>
<td>Support both collaboration and independent work</td>
</tr>
</tbody>
</table>

4.4 System Design

The AB–WINDEC prototype was designed to meet the specifications in the framework. First, stakeholder personas were profiled according to their interests, tasks, and information seeking behaviour. The idea was to provide stakeholders with data and system capabilities that are tailored to their specific tasks and needs. This technique emphasizes the human-centered design, and has been discussed in detail by Cooper (1999) in his book, *The Inmates Are Running the Asylum*.

Further, in consideration of the requirement to integrate the models with the data management system and tasks sequence, we developed a modular design with five interacting modules. The modular design is based on the approach demonstrated by Chamberlain et al. (2012) and Niekerk (2009). Figure 4.1 shows the structure of the design.
Figure 4.1. Schematic representation of the AB–WINDEC system structure

The design incorporates modules that can be altered or replaced without affecting the overall functionality of the system. We adapted the task categories as a model for the modular design. The modules in AB–WINDEC are designed to operate independently or within the decision task categories. In this way, the system interface is composed of different modules such as: Research
module, Analytics module, Design Module, Evaluation Module, Reporting Module. Each module has a specific functionality and sub-modules that uniquely support the decision analysis.

4.5 Prototype implementation

The implementation of AB–WINDEC evolved mainly from interdisciplinary principles and methods drawn from the fields of research:

- **Product Experience Design** (Hassenzahl & Tractinsky, 2006; Tullis & Albert, 2008);
- **Human Computer Interaction** (Dix et al. 2005; Hassenzahl 2005; Veryzer and De Mozota 2005; Zimmerman et al. 2007; MacDonald 2012);
- **Visual Analytics** (Thomas and Cook 2005; Scholtz 2006; Thomas and Cook 2006; Wong 2007; Thomas and Kielman 2009; Wang et al. 2009; Arias-Hernández et al. 2011; Adagha et al. 2015b [in chapter 3])

The implementation methods are briefly discussed below.

4.5.1 Prototyping

The prototyping technique was used to implement the design of AB-WINDEC to ensure that the proposed design is consistent with stakeholders’ needs. Prototyping also allowed us to conceptualize the functional elements and to make refinements along the way.

4.5.1.1 Horizontal prototypes

Prototypes can have horizontal or vertical dimensions (Holmquist 2005). The current design was implemented as a horizontal prototype. This allowed a focus on the interface design without the need to implement full back-end functionality. A vertical prototype, on the other
hand, would require a detailed technical elaboration of the internal functions, which was beyond the scope of this work.

**4.5.2 Fidelity transitions**

Walker et al. (2002) defined fidelity as the level of resemblance a prototype shares with the final product. Our design methodology was supported by an experimental study which showed that multiple fidelity transitions are useful for designing user interfaces (Coyette et al. 2007). We used multiple fidelity transitions as a systematic model for developing the prototype design.

We began the implementation process with low fidelity paper prototypes, which later transitioned to a functional and interactive medium fidelity prototype. The transitions are described briefly below.

4.5.2.1 From concept to low fidelity prototype

The low fidelity prototypes provided a rudimentary overview of the design direction. In order to illustrate the potential of computer-support, we sketched the interface screens and menus using the pen and paper media. This meant the flow of ideas and concepts were less constrained. This version of the prototype focused specifically on the content and layout of the user interface, with a view to ensure that the interface layout fulfilled the requirements specifications.

4.5.2.2 From low-fidelity to medium fidelity

A medium fidelity prototype was developed using the Axure RP software. Axure is an interactive wireframe and mock-up tool that supports different interaction events, web fonts, string functions, and adaptive prototypes (Schwartz and Srail 2014). We made the transition from the paper mock-ups to medium fidelity to implement interactive elements and visual aspects of the prototype on a computer system. This version of the prototype allowed us to define
navigational aspects, interface functionalities, content and layout components in a more approximate form. Figures 4.2 – 4.4 shows three examples of the fidelity transitions from concept to medium fidelity prototype. Realistic interfaces are first implemented in low fidelity according to the specifications in the conceptual framework.

Side-by-side execution in juxtapose shows the following transitions:

a. The “welcome page” evolves from concept and is implemented on an interactive, web-based interface. (see Figure 4.2)

b. The “search interface” evolves from concept and is rendered on an interactive, web-based interface. (See Figure 4.3).

c. The “data viewer” evolves from concept and is realized as a prototype interface that can support interactive visualization and data analysis. (See Figure 4.4).

4.5.3 Web-based Integration

The medium fidelity prototype was implemented on a web-based platform. The prototype was developed as a web-based application to allow for ease of use, interoperability, and data management as outlined in the conceptual framework.

Due to recent advances, web-based visualization of information graphs, charts, and map and data interaction can be dynamically built and rendered on a web page (Stockton et al. 2012). Web database applications have two constituent parts: (i) a database representing the memory; and (ii) an application that performs the tasks (Bello-Dambatta 2010). In AB-WINDEC, Google Drive, Mapbox, Shape Escape and Fusion Tables provide an ad-hoc database functionality.
**Concept:**

- Specific context of application (Alberta)
- Specify purpose of the tool
- Design intuitive login interface with content tailored to specific stakeholders’ personas

*Figure 4.2. Fidelity transitions in the "welcome page"*
Concept:
- Clarify purpose of the tool
- Facilitate research
- Facilitate data integration

Figure 4.3. Fidelity transitions in the “Search interface”
Figure 4.4. Fidelity transitions in the “Data viewer”
Axure RP was used to generate the HTML and JavaScript code so that the prototype can be accessed through web browsers like Internet explorer, Firefox, Safari, or Chrome.

Fusion Tables is a modern data management web application making it easy to upload, manage, parse, collaborate on, visualize, and publish data online (Gonzalez et al. 2010). Stakeholders can view and interact with the prototype on the Web without installing it as an application. Google drive and fusion tables are frequently used together because they have built in features for communicating with each other (Bradley et al. 2011; Zhu 2012; Bowie et al. 2014). Mapbox is an open source application for creating informative, shareable, interactive and customized maps from spatial data. Mapbox draws from large spatial sources that include OpenStreetMap, USGS, Landsat, Natural Earth, and OpenAddresses and was used as a spatial data repository. It includes standard data visualization features (zoom, pan, layer management, etc.) as well as dBASE filename extension attribute for table editing, shapefile editing, and grid importing and conversion. Shape Escape is also an open source application that provides a filtering mechanism for the conversion of Shape files to Keyhole Markup Language (KML) files via a two-step process. Because of its tag-based structure – with nested elements and attributes, KML can be easily adapted to visualize geospatial data on map or chart (Zhu, Wang, & Zhang, 2014).

Once a connection has been made to the database via Shape Escape, the data may be stored locally and can be accessed through the data manager. Combining Google Drive with Fusion Tables, Shape Escape, and Mapbox JavaScript greatly reduces the file size and makes data transfer more efficient; and this allows for a fully-functional, web-based visual analytics system.

Furthermore, we used the Jotform API plug-in to generate reports for the Reporting and Evaluation Interfaces. Jotform provides web output as a single HTML document. Additionally,
the Jotform API allows the functionality of exporting the data to spreadsheets and Microsoft Access. We also use the API to deliver intuitive charts through the Report Engine.

The prototype is hosted on a dedicated website, making it possible for a range of stakeholders, from regulators, planners, developers to landowner organizations, to access the tool. Given that AB–WINDEC was designed a web-based application, stakeholders would require minimal hardware and software capabilities to operate it.

4.5.4 Expert Appraisal

We conducted a preliminary evaluation to identify any potential usability problems and to ensure that the proposed design satisfied the requirements outlined in the conceptual framework. We used the expert appraisal method to perform this evaluation. Expert appraisal is the evaluation of a product by someone who has professional training or experience to make an informed judgement on the design (Clarkson et al. 2007). This method is similar to the heuristic evaluation method proposed by Nielsen and Molich (1990). The main difference is that heuristic evaluations focus more on usability testing and analysis of interfaces, whereas expert appraisal takes a more holistic product assessment approach (Nieveen 1999).

An interface design expert was invited to evaluate both the low-and medium-fidelity prototypes, and to provide feedback on the strengths and weaknesses of the emerging design. Prior to the assessment, the expert was provided information on the background research, the nature of the tasks, and the persona requirements. The expert then studied the prototype and performed several demonstrations of the system. The expert recommended improvements in the following areas:
- Interface navigation and functionality
- Data visualization
- Windowing and pane management
- Layout consistency and organization
- Effective use of visual elements
- Use of appropriate information representation
- Iconography
- Efficiency
- Consistency of the terminology
- Clarity of concept representation
- Consistency of the interaction mechanisms

Following the evaluation, we incorporated the expert’s recommendations in the design and implementation of the prototype.

4.6 AB-WINDEC characteristics and capabilities

AB–WINDEC was implemented using closely linked, but independently developed modules as shown in Figure 4.1 (system structure design). The prototype functionality is divided into five distinct but related parts, namely:

- Research Module
- Analytics Module
- Design Module
- Evaluation Module
- Reporting Module
In the modular architecture, each module has specific functionalities and routines that can support the decision process. The modules were implemented in Axure RP and then linked with interactive codes bearing the thematic maps and analytic charts. The functionalities of the modules were developed according to the decision support requirements defined in the conceptual framework. The interfaces were designed to facilitate linkages between the modules. In this section, we discuss the different modules, interfaces, and the full scope of the prototype’s intended capabilities. Figure 4.5 shows a screenshot of the Main Interface.

![Figure 4.5. A screenshot of the main interface, showing an overview of individual modules](image)

### 4.6.1 Login Interface

The primary function of the login interface is to facilitate access to all sections of the prototype. When logging in, stakeholders are given the option of accessing the system with a
specific persona relating to Developer, Landowner, Consultant, Researcher, Regulator, Conservation analyst, Climate Change advocate, and Member of the public. With this interface, the stakeholder personas requirements discussed earlier in section 4.2.1 is addressed. The personas login approach is designed to facilitate individual access to information and task support features tailored to the stakeholders needs. This approach will reduce the amount time spent in finding analytical solutions. Figure 4.2 provides a snapshot of the login interface.

4.6.2 Research Module

The Research module provides access to a search interface and Data Manager which are both connected to local internet databases as described in section 4.5.3. The Research module is designed to satisfy the information-seeking requirements of stakeholders. The data integration capabilities allow alternative methods of accessing the multiple datasets available within AB-WINDEC. The search bar simulates the information search experience as required by stakeholders.

The datasets in the database can be assessed from the search interface and integrated into the Data Manager. Stakeholders can upload and analyze their own data via the Data Manager. With this functionality the system can also act a data repository. Drop down menus allow stakeholders to also download or upload data to the system. Furthermore, the Data Manager interface provides a conduit through which spatial datasets and databases from Alberta can be searched, filtered, and visualized in analytical charts and maps. For example, stakeholders can use the Data Manager to define a custom data query using varying criteria, and then export the selected data to the map and chart viewer to create interactive data displays. Stakeholders who upload their own data can have "working storage" functionality for such data sets.
The data integration capability also helps to integrate different analytical models in the system. This means that information-seeking and data visualization queries can draw from various analytical models that are embedded in the system. The data integration capability is illustrated in Figure 4.6.

![Figure 4.6. A screen shot of data uploads to the data manager, hosted on google drive. The ad-hoc back-end can respond to analytical and visualization queries in the data viewer.](image)

### 4.6.3 Analytics Module

The Analytics Module provides a visual platform for analyzing data. The interface is designed with two coordinated visualizations: a map display and a chart view. Each section can be tailored to specific datasets which are generated from the Data Manager.

The customizable charts and maps are designed to provide analytical index for stakeholders to visualize predefined data on wind farm placement issues. Another interesting feature about the
*Analytics Module* is that it provides the stakeholder with a visual rendering of the issues on a spatial, qualitative and quantitative scale. The map viewer and analytic viewer were developed as a technical solution to visualize datasets (see figure 4.7). The data used in planning the placement of wind farms are of different spatial, temporal, and thematic resolutions. In consideration of the massive amount of data that have to be analyzed during the decision process, we grouped and rendered them through themes. In this way, the data in AB–WINDEC are managed as thematically organized information layers. Using this approach, stakeholders can visualize the selected data in the form of color-coded maps which can support assessment of locations where wind farms may or may not be appropriate.

![AB-WINDEC](image)

*Figure 4.7. The data viewer shows an interactive map-based visualization of ‘park and protected areas’ within Alberta, and interactive chart visualizations of ‘wind speeds’ and ‘industrial noise levels’ at different locations.*
4.6.4 Location Assessment Model

The Location Assessment model is a simulation tool in AB–WINDEC whose intended purpose is to enable stakeholders to develop and evaluate possible locations for wind farm development in Alberta. The model framework aims to combine the strengths of the multi-criteria and the analytic hierarchy process (AHP) techniques of addressing land use compatibility, land use suitability, and land use allocations, similar to the approach advocated by Anjomani (1992) and Mendoza (2000).

The AHP approach allows for a unified, multi-stage assessment of land suitability that can be defined in a relatively objective manner (Saaty 1987). Adopting it as a Location Assessment model can help facilitate a straightforward evaluation of different types of criteria, for example, conflicting land use issues, regulatory setbacks, wind availability, land titles, noise, and wildlife, and inclusion of existing land uses in location assessment. Furthermore, the approach relies less on the completeness of the data set, and more on stakeholders’ opinions about the different factors and their perceived effects on land suitability. In addition, the AHP approach is more transparent because it allows for the participation of stakeholders in the incorporation of both qualitative and quantitative criteria for assessing land suitability relative to a proposed wind farm development, and hence more likely to be accepted by stakeholders. These advantages are lacking in alternative approaches such as pure statistical techniques and traditional GIS-based multi-criteria analysis.

In AB–WINDEC, the Location Assessment interface is operationalized in eight sections. Each section is designed to represent one of the key issues that influence wind farm placement.
planning decisions in Alberta. For the medium-fidelity prototype, only the front-end capabilities were implemented for demonstration purposes (see figure 4.8).

![Image of Location Assessment model](image)

**Figure 4.8. A medium fidelity implementation of the Location Assessment model**

However, in the conceptual model operation, we propose a two-stage optimization procedure that will determine whether wind farm placement is compatible and suitable at a specific location. We suggest that the location assessment process should begin at Stage 1, where the compatibility of a selected location with wind farm development can be determined using a simple linear equation:

\[ C = L \times K \]

Where:

- **C** is the high-level compatibility of a land location in Alberta for wind farm development.
- **L** is the spatial land location in Alberta.
\( K \) is a constant variable representing the type of land and its compatibility or non-
compatibility for wind farm development in Alberta. \( K \) is assigned a binary variable of 0 and 1,
with 1 representing private lands and 0 representing Crown Lands and Metis Lands. This is
because wind farm development is currently allowed only on private lands in Alberta.

In stage 2 of the process, we propose that relative suitability of a land location for wind farm
placement, that has passed the stage 1 compatibility test, can be calculated using an optimization
model that recognizes existing land uses, conflicting land use issues, regulatory setbacks,
national, regional or municipal land use policies, wind availability, land titles, noise, mitigation
of potential impacts on the environment, and other likely factors that are peculiar to the Alberta
terrain.

This can be achieved by using the following mathematical model:

\[
SL = \sum_{C=1}^{n=100} W_C J_C
\]

The linear relationships in the optimization model can be defined as follows:

Where:

\( SL \) is the measure of suitability of wind farm development at land location \( L \).

\( C \) is the compatibility index of a land location in Alberta for wind farm development. The
compatibility index is presumed to be 1 if the proposed location is on private land.

\( J \) represents the location specific factors or issues that affect the suitability potential of a land
location for the purposes of wind farm placement. This can be specified based on stakeholders’
knowledge of issues affecting land use locations for wind farms (see chapter 2).

\( W \) is a coefficient representing the quantitative or qualitative weight assigned to the land use
issues or factors that are specific to Alberta (e.g. number of turbines, wind speed, noise level,
setbacks, distance to roads, etc.) in the analysis of wind farm placement. To determine the weights, consideration of the factor types, and the set of possible datasets for a particular factor, is recommended. Such information can be generated from studies designed to elicit the stakeholders’ judgment and opinion (see chapter 2 and chapter 5). The coefficients can be extracted from regulatory requirements such multi-agency constraints and setbacks in Alberta, as well as national, regional, and municipal land use bylaws.

Table 4.2 shows the conceptual suitability index values and the corresponding categories that can be obtained from the model equations.

The location assessment model was adapted from earlier models proposed by Mendoza (2000), and is being specified in this manner for the first time. Data for the variables used in the location assessment calculations can be built into AB–WINDEC or assessed from local databases, bylaws, and regulatory requirements. The model, as described, can be easily transformed and implemented in a computational environment.

<table>
<thead>
<tr>
<th>Suitability score</th>
<th>Location suitability category (S_L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;80</td>
<td>Highly suitable</td>
</tr>
<tr>
<td>&gt;60</td>
<td>Moderately suitable</td>
</tr>
<tr>
<td>&gt;50</td>
<td>Marginally suitable</td>
</tr>
<tr>
<td>40-50</td>
<td>Marginally unsuitable</td>
</tr>
<tr>
<td>&lt; 40</td>
<td>Highly Unsuitable</td>
</tr>
</tbody>
</table>
4.6.5 *Design Module*

The *Design module* is a suite of drawing tools designed to support stakeholders with the skills to design the wind farm layout. The drawing tools allow for collaborative work among stakeholders and, in turn, facilitates the effective iteration and optimization of the key parameters for the turbine placement layout at early design stages. For example, following the analysis stage, decisions such as defining the buildable area, establishing a constraints layer, and photo simulations are made. The *Design module* can support the evaluation of project feasibility along with other requirements, increasing energy yield, reducing visibility footprint, reducing noise and shadow flickers. The interactions on the drawing and sketch boards can be displayed in real time, thus greatly increasing the potential for expert stakeholders to develop synchronous wind farm layouts collaboratively with regulators and landowners.

4.6.6 *Evaluation Module*

A key design concept in the AB-WINDEC system design is the addition of the *Evaluation Module*. The module is designed to allow stakeholders, especially those with regulatory responsibilities, to review applications electronically. The Evaluation Module is also designed to ensure compliance with regulatory setbacks and to help reduce time spent on tasks. These capabilities are supported by the database system. We envision the *Evaluation Interface* as a lens through which all wind farm design and development proposals can be evaluated.

4.6.7 *Reporting Module*

The Reporting Module is designed to support different stakeholders to standardize their reports, access ongoing applications and make changes as required. An important feature of these interactions involves communication on the status and viability of wind farm development
applications. Designed with inbuilt template reports, the Reporting Interface makes it easy to deploy, view, and manage secured and interactive documentation at crucial stages in the decision process. When in operation, a wide variety of intuitive charts like bar, pie, point, line, etc. are linked to the analytic viewer and can be inserted into the reports. Reports and charts are then generated from a report engine. In this way, the Reporting Module can thus improve coordination between stakeholders and reduce the time spent on tasks.

4.6.8 Examples of AB–WINDEC Capabilities

4.6.8.1 Visual Analysis of data

Initial investigations in the planning process of wind farm placement usually involve analysis of multiple datasets (see chapter 2). Using wind speed as a reference point, Figure 4.7 shows three different visualizations of wind speeds on the AB–WINDEC data viewer. Stakeholders can import their own or use the data in AB-WINDEC. During analysis, the stakeholder can view different visualizations of the same data, and can thus analyze information on the wind speeds at different locations.

4.6.8.2 Buildable Area Design

The buildable area of a site can have a significant impact on how placement decisions are made. Buildable area design can be constrained by planning or zoning requirements like height limits, setbacks, risk of wildlife mortality, and other zoning envelope restrictions. With AB-WINDEC, stakeholders can design the buildable area of a potential site in both horizontal and vertical directions, using the simple drawing tool. Figure 4.9 shows a simple buildable area design in AB-WINDEC.
4.6.8.3 Location Assessment Analysis

The Location Assessment interface allows a stakeholder to apply different weights and site selection criteria to each land use issue. Following selection of the criteria and weights, the stakeholder can click on the decision bar button, which then renders a location assessment result based on the criteria selected. The analytical assessment is delivered in a Decision Bar with a percentage scale of 1 to 100 (Figure 4.10). This range reflects the suitability of a location in relation to other land use issues, project viability considerations, regulatory requirements and other parameters that may be specified by stakeholders. The Decision Bar scale has a color-coding scheme, where green represents suitability and red indicating unsuitable locations.
When fully operationalized, the Location Assessment model can perform the following tasks:

- Specify criteria weights
- Specify suitability ratings
- Compute suitability scores
- Analyze suitable locations for wind farms based on input from stakeholders.
- Generate a suitability report

4.7 Discussion

A discussion on the challenges of translating stakeholders’ requirements into design choices must start with an understanding of the core functionalities of the proposed system.

AB–WINDEC is designed to be a fully interactive visual analytic decision support tool, supporting the stakeholders through all the tasks typically involved in wind farm placement planning decisions. In this section, we discuss the key concepts and ideas that influenced the design process.

4.7.1 Design Goals

The primary goal of this project was to design and implement a tool that can support stakeholders’ assessment of potential wind farm placement locations in Alberta. To achieve this,
we needed a process by which we can simulate, test, and improve these experiences without consuming time and development resources. We also needed an intuitive design tool that has wire-framing and prototyping capabilities. Axure RP was useful in this regard. With Axure RP, it was possible to simulate different interaction techniques and layout navigations on the prototype using simple wireframes.

The second goal was to simplify usability. We designed the tool to support basic computer skills of stakeholders involved in wind farm placement decisions in Alberta. Thus, it was necessary to incorporate functionalities such as portability, ease of use, visual analysis capability, and interoperability across platforms in the design. To further aid stakeholders understanding of placement issues, we used simple and realistic visualizations to represent complex decision issues and land use information.

Having determined that proprietary tools restrict the involvement of key stakeholder groups in the decision process, a further aim was to develop a functional prototype which can exist as an open-source tool. Throughout the development of process, our approach was to use open source platforms as the main development environment for the prototype. A major advantage of using an open source development platform is that the prototype can potentially attract contributors who may continue the development.

### 4.7.2 Design Considerations

According to Beaudouin-lafon & Mackay (2003), design is process of making choices. In this section, we discuss and justify some of the choices and considerations that guided the prototype development.
4.7.2.1 Prototyping design approach

The prototyping method informed the design process of AB–WINDEC in many ways. First, it enhanced creativity, generate ideas, and to check how well design concepts addressed the decision support requirements at different fidelity levels. It provided a cheap and easy means to review the design and to make improvements accordingly. It also facilitated the design evaluation process, through expert appraisal, during the implementation stages.

4.7.2.2 Modular design approach

The decision to adopt a modular design addressed a crucial link between task flow and data integration in the Alberta wind farm planning decision process. In this respect, AB–WINDEC was designed to allow stakeholders and decision makers to manage projects from beginning to end. The modular approach also ensures that different modules can be changed or even replaced without affecting the functionality of the system. This was deemed important because we expect that the AB–WINDEC design may be modified and expanded in the future. Another consideration that informed the modular design approach was that it lends flexibility to web-based configuration as changes to the prototype will not affect individual modules. The modular approach was used to simulate our current understanding of the work flow patterns in the decision process.

4.7.2.3 Web-based platform

The AB–WINDEC was envisioned as a web-based application. Our decision was influenced by technical and functional considerations. Technically, there is a large and expanding resource pool of software and hardware resources for implementing web-based prototypes (Black and Stockton 2009). Deploying a web-based tool will reduce technological barriers, making it easier
and less costly medium to make information available to stakeholders (Power and Kaparthi 2002; Bhargava et al. 2007).

From functional perspective, stakeholders are increasingly relying on the Web as a source of information to support decision-making (Jarupathirun and Zahedi 2007). The knowledge that decision-making and decision support activities tend to be ubiquitous in nature, makes the internet an ideal platform for implementing prototypes with decision support capabilities – specifically prototypes of tools that can facilitate spatial analysis and stakeholder collaboration (Mysiak et al. 2005b; Carlon et al. 2007; Monte et al. 2009). Following the transition to the medium fidelity prototype, we used an ad-hoc web-server to perform most of the data processing and visualization tasks.

4.7.2.4 Thematic and analytic visualizations

Interactive information visualization and visual analytics (Thomas and Cook 2005; Ribarsky et al. 2009) were key components in the design of AB-WINDEC. A consideration that arose during the design stages was how to structure and visualize the spatial datasets involved in wind farm placement planning. In AB–WINDEC these data are under specific themes, for example all noise data were grouped as a thematic layer in the database.

This helped to facilitate direct data integration from the data manager, whereby the selected data themes can be propagated to the map viewer or chart viewer in the form of color-coded visualizations on maps and charts. This quality make AB–WINDEC well-suited to complex data analysis tasks.

4.7.2.5 Context-specific and place-based design

The proposed tool, as outlined in the framework, must be applicable to the wind farm placement planning decision process in Alberta. Therefore, a ‘place-based approach’ was
adopted in the design of the tool. For complex application domains such as wind farm placement planning, a place-based approach helps to provide insight and context to conflicting land use issues (Tomaszewski 2007).

The approach taken here included: naming the tool according to the local context, integration of local data sets, and the simulation of the Alberta wind farm placement ‘decision path’ in the prototype layout. The ensuing design also takes account of the values and goals of stakeholders, evolving scientific information, and their perceptions of risk.

4.8 Limitations

It is important to note that every development environment imposes constraints on the interface design and implementation, limiting creativity and restricting the number of design solutions considered. The prototyping and wire-framing methodology we used in the design allowed us to display a wide range of features but without fully implementing the back-end and data management aspects of the design solution. Due to this approach, the design and implementation choices were determined by budgetary and time limitations. For example, building a complete back-end component, with all the required attributes, would have been a difficult undertaking and beyond the scope of this project. At this point, the prototype has been designed for demonstration purposes only. Nevertheless, evidence strongly suggest that the design and the demonstrated functionalities can be successfully implemented in a high fidelity prototype.

The expert appraisal routine was a quick and easy way to obtain feedback and recommendations. It may be possible that the personal bias of the expert may have influenced their recommendations. We have tried to mitigate this by providing the expert with a thorough
background information on stakeholder personas, tasks, workflow, and usability preferences. Due to time and budgetary constraints, we could not use several experts in the evaluation.

Presently, the mathematical model proposed for the location assessment tool has not been implemented as a computer model or verified to check whether it can perform the conceptual calculations. Such approach would be necessary to assess the correctness of the model. Nevertheless, the location assessment tool in the prototype successfully simulates the intended purpose of mathematical model, which is to allow stakeholders to manipulate different land use scenarios and analyze the results of various inputs (i.e. similar to a "what if" analysis). Importantly, the model is dimensionally consistent and relates strongly to both mathematical principles and socio-technical considerations.

The AB–WINDEC prototype has been developed to medium fidelity levels. However, it will require further evaluation and development before it is fully ready for ‘use’ in wind farm decision support tasks in Alberta.

4.9 Future Work

While the implementation of AB–WINDEC is a crucial first step, many problems remain to be solved. Clearly, additional requirements are needed to help refine the design, improve its performance, and enhance its capabilities. Having developed the prototype up to medium fidelity levels, it would require further evaluation and input from stakeholders before it is fully ready for ‘use’. This stems from the need to adapt the system’s design more closely to the needs of stakeholders.

In future work, we intend to use the prototype as a medium to communicate design ideas to stakeholders. As a result, a critical next step in the development of this tool is to work with
stakeholders to determine how well the tool reflects their needs. Accordingly, we plan to conduct a series of focus groups to evaluate the tool and to gather feedback from stakeholders. Feedback from stakeholders will form the basis for further refinements.

4.10 Summary and Contributions

In this chapter, we developed a conceptual socio-technical framework and a proof-of-concept prototype based on decision support requirements obtained from stakeholders involved in planning wind farm placement locations in Alberta. We also demonstrated clear understanding of the requirements that allowed us to define the scope, structure, design, and implementation process. The prototype’s functionalities were designed to reflect the needs of stakeholders in Alberta. This is evident in the simple design, automated data flow, task-oriented interface, web-based platform, multiple data displays and interactive visual analytics. The AB–WINDEC is designed as a tool that can adapt to human-defined analytical paths. The decision support system described in this paper was intended to integrate and visualize place-based information to support analysis related to determining suitable locations for wind farm placement in Alberta. The capabilities of AB–WINDEC are shown in supporting these activities.

From a socio-technical perspective, we have demonstrated a new approach of translating requirements into concrete design ideas and functionalities. AB–WINDEC responds to the need for adapting the decision support tool to the decision process, incorporating the main decision issues, handling data, and engaging stakeholder background knowledge and preferences. Through this process, we have conceptualized requirements gathering and prototypes as worthwhile design tools.
Finally, AB–WINDEC has both data-and-model-driven architectures, thus bridging the gap between data-driven and model-driven decision support tools. The novelty is that AB–WINDEC can allow access to multiple data sources, and also allow for model-driven systematic framework, land use simulation, and quantitative analytical capabilities. These two approaches complement each other in many ways, leading to improved data analysis and wind farm placement considerations.

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Chapter Five: Evaluation of a Prototype Tool for Wind Farm Placement Planning In Alberta: Findings from a Focus Group Study

Abstract

The knowledge of how usable and useful decision support technologies can be successfully developed is crucial to increasing their acceptance in real-world settings. Although the incorporation of requirements, design methods, and frameworks add some benefits to the development process of decision support tools, however, these does not offer a complete solution. A more effective strategy requires the participation of stakeholders in evaluation studies. Focus groups can play a major role in communicating design ideas to stakeholders and in soliciting feedback on a tool’s usability and perceived usefulness. This chapter presents the findings of a focus group evaluation study of the Alberta Wind Energy Decision Support tool (AB-WINDEC) prototype. Feedback from participants’ generated additional requirements and design concepts that could be used to develop the prototype further. The results of the study also extended current knowledge of how stakeholders interact with tools and what is required to effectively support wind farm placement decisions. Finally, the findings provided insight on potential barriers that can influence the acceptance and use of AB-WINDEC.

5.1 Introduction

The understanding of how decision support tools can be developed and successfully integrated into decision processes is critically important in increasing their acceptance (Maguire 2001; Kushniruk and Patel 2004). Many poorly designed systems exist because often the perspectives of the people who use the systems are not considered integral to the development process (Lu and Cai 2000).
Following the design and implementation of a proof-of-concept prototype decision support tool (AB–WINDEC) for wind farm placement planning in Alberta in chapter 4, evidence abound (see, Sojda 2007) that, for effective development of decision support tools, it is necessary to assess the impact, usefulness, and usability of the prototype and to draw further design knowledge from the evaluation studies. AB–WINDEC is designed as a visual analytics tool that can provide functionalities such as data integration and management, task support, interactive analytics, and thematic visualizations. The evaluation of the prototype would provide feedback information and a better understanding of the problem in order to improve both the quality of the product and the design process (Hevner et al. 2004).

There are many ways in which this knowledge can be elicited in evaluation studies. These include questionnaire surveys, usability inspections, cognitive walkthroughs and observation of stakeholders operating the prototype in real-life situations. More recently, though, there has been a growing trend of using focus group methodologies to support these more conventional methods (Langford and McDonagh 2003). This is largely because the interactive and synergetic nature of group discussions allows deeper insights and can facilitate more useful feedback on product design in ways that may not be possible with other methods (Krueger and Casey 2001). Furthermore, feedback from focus groups may have a greater chance of identifying new concepts that can be used to refine the design of a prototype system (Nunamaker and Chen 1990; Anastassova et al. 2007). Thus an empirical design evaluation should seek answers to questions such as:

- What is the overall experience of using the prototype?
- What are the useful and not-so-useful features in the prototype?
- What are the usability challenges encountered on using the interface?
• What additional features are needed to improve ease-of-use?
• In what ways did the prototype meet stakeholder’s needs, and what changes would improve its decision support capabilities?
• Are there any tasks that are not currently supported by the prototype?
• What other applications should be considered when re-designing the prototype?
• What are the barriers to use and integration?

In this chapter, answers to these questions are rigorously pursued through a series of focus groups with stakeholders in the Alberta wind energy sector. To present the findings, the chapter first describes the background research that gave birth to AB-WINDEC. It then reports on the methods used in conducting the focus groups. This is followed by a discussion of the findings, study limitations, and future work. The chapter concludes with a brief summary of the implications and topics for future work.

5.2 Background

Some empirical studies have helped to give focus to this evaluation study. These are briefly summarized below:

5.2.1 Development of the AB–WINDEC decision support tool

Can decision support tools be designed to meet the specific information needs and requirements of stakeholders? This concept was demonstrated in the Alberta Wind Decision support system (AB–WINDEC) – a prototype decision support tool that brings together different functionalities, analytical models, and visualization capabilities, to help stakeholders gather, structure, and analyze data when assessing placement locations for wind farms in Alberta (see chapter 4). As the name implies, the AB–WINDEC is place-and-context specific. The system
design was developed through a conceptual framework, adapted from stakeholders’ decision requirements in chapter 2 (Adagha et al. 2015a). Further, in consideration of the requirement to integrate the models with the data management system and tasks sequence, the prototype was developed using a modular approach.

The design incorporates five modules that can be altered or replaced without affecting the overall functionality of the system. In this way, the system interface is composed of different modules such as: Research module, Analytics module, Design Module, Evaluation Module, Reporting Module. Each module has a specific functionality and sub-modules that uniquely support the decision analysis. Figure 5.1 shows a screen shot of AB-WINDEC’s main interface.

The system was developed as a web-based tool to reduce technological barriers and to make information more easily accessible to stakeholders. The prototype development process and capabilities are fully documented in chapter 4.

Figure 5.1. A screen shot of the main interface, showing an overview of individual modules
5.2.2 Design and evaluation attributes for visual analytics tools

What attributes are needed to enhance the human-product interaction experience in visual analytics decision support tools (VADS)? In Chapter 3, see also (Adagha et al. 2015b), there is some discussion as to the attributes of effective tools and how their impact can be measured. The findings introduced a general framework of attributes that could yield insights into how people perceive these tools in relation to their needs. For example, the chapter argued that a person’s experience of visual analytics is shaped by the ability of the tool to support creativity, utility, situation awareness, collaboration, and interaction. These attributes are distinguished in having their different underlying metrics.

So far, the attributes proposed in chapter 3 have not been applied in real world settings with visual analytics tools. The study in the chapter offers the opportunity to apply them in a focus group evaluation of AB–WINDEC with wind energy stakeholders.

The present chapter builds on the groundwork in chapters 2, 3, and 4 in this thesis, by focusing specifically on how well the prototype reflects the requirements of stakeholders, and what is needed to improve its effectiveness and usefulness as a visual analytics decision support tool.

5.3 Material and Methods

5.3.1 Study design

Focus groups were convened to evaluate the AB–WINDEC prototype tool with wind energy stakeholders in Alberta. A focus group is a method of research that utilizes group discussion to solicit ideas and feedback about a concept or product (Morgan and Krueger 1998). In focus groups, participants can interact directly with new technologies, articulate their ideas, and
provide researchers with inspiration for the design process (Bruseberg and McDonagh-Philp 2002; Langford and McDonagh 2003).

Some objectives motivated the study. The first is that it was necessary to evaluate the utility and effectiveness of the proposed prototype with real stakeholders who are involved in wind farm placement planning. Another goal was to demonstrate the vision of the tool design to stakeholders through a more inclusive form of research (Bertrand et al. 1992). A further goal was to assess how well the prototype met functional goals and usability needs of stakeholders and to stimulate technical innovation. The final goal was to explore insights and concepts that can be used to improve the design of the prototype.

The focus group sessions were conducted between March 2015 and April 2015. Three focus groups were conducted separately in meeting rooms at the University of Calgary campus while one focus group was held in Edmonton. Each focus group session was conducted by a skilled moderator and one assistant. The moderator was responsible for keeping the participants focused around the key questions and to facilitate an open discussion. The assistant’s tasks were to take notes, distribute study materials, and assist the moderator. The sessions were conducted in English and each session lasted approximately two hours.

5.3.2 Pilot Study

A pilot study was conducted with university students of the Master of Planning program at the University of Calgary. The purpose was to develop and test the adequacy of the research instruments and methods. It was also used to practice the roles of the research team, and to evaluate how the survey population might respond to the interview questions and questionnaires. The pilot study highlighted potential problems such as, poor response to the survey questions.
Following the pilot study, the questionnaire layout was redesigned, and some ambiguous questions were either re-worded or discarded.

5.3.3 Participants

With the endorsement of the University of Calgary’s CFREB research ethics committee, the research team enrolled a convenience sample of seventeen participants. There were altogether four focus groups with 3 to 5 participants each. This range, as suggested by Onwuegbuzie et al. (2009), allows for sufficient variation in the discussions. Participants were recruited through official invitation letters sent by electronic mails. Written consent was obtained from the participants before the start of each focus group. Participants were also informed about their right to withdraw at any point.

5.3.4 Participant inclusion criteria

Purposeful sampling was undertaken, following the approach prescribed by (Erlandson et al. 1993; Onwuegbuzie and Collins 2007), to ensure a heterogeneous mix of stakeholders with different backgrounds and interests. The stakeholders were identified based on their experience and their level of involvement in the wind energy sector in Alberta.

Specifically, individuals who met any of the criteria below were targeted:

- Adult (over the age of 21)
- Have reasonable knowledge of, and demonstrated interest in, the issues that relate to the placement of wind farms in Alberta;
- May be affected, or believe that they could be affected, by the placement of wind farms in Alberta;
- Can influence public opinion about wind farm placement and associated land use
issues; or

- Have authority to make land-use decisions affecting wind energy placement in Alberta.

The final sample included wind industry professionals, land owners, analysts, planners, developers, regulators, and consultants (see Table 5.1). More importantly, the focus group participants represent the population who will use, or supervise the workforce who will use, the proposed decision support tool to be evaluated in this study. Figures 5.2 and 5.3 give an overview of some of the group sessions in progress.

Figure 5.2. A cross-section of focus group participants evaluating a design concept
5.3.5 *Procedures for Data Collection*

At the beginning of each focus group, the moderator introduced himself and gave a brief explanation of the procedures to the participants. The data collection proceeded in four steps.

5.3.5.1 Pre-study questionnaire

Before the focus groups began, participants were asked to complete a pre-study questionnaire. This questionnaire was used to collect demographic data which allowed for a better depiction of the focus group participants (see Table 5.1).

*Figure 5.3. A cross-section of another set of focus groups participants in a session*
Participants were then shown a PowerPoint presentation describing the background research and the conceptual framework that informed the structural design, the key functionalities, and the capabilities of the AB–WINDEC prototype. Following the presentation, participants were asked to click through the prototype interfaces and menus in a self-directed fashion.

5.3.5.2 Sketches and notes

To give more depth to the focus group data, participants were provided with blank sketch papers and printed versions of the prototype’s interface. On the computer screen, participants were let to freely explore the prototype. However, for links that were not interactive, or had not been fully developed, the following message was made to appear on the screen:

‘This section of the tool you have now selected is still undergoing development.
We would like your help. Please tell or show us, through writing or drawing, what you would expect to find on this page.’

Participants interacted directly with the system and these interactions provided some insights into the usability of the interface. Following this, participants were then encouraged to write notes, draw alternative sketches, or make suggestions or ideas, they may have of each interface, on the sheets provided to them.

The primary aim of this technique was to gain a deeper understanding of the stakeholder requirements beyond the data already provided by the focus group discussions and surveys. The technique was adapted from the blank page technique proposed by Still and Morris (2010). Selected and anonymized samples of the sketch illustrations by participants are offered in Appendix A.
5.3.5.3 Group discussions

The discussions were semi-structured. To facilitate the discussions, the prototype interfaces was shown, page by page, on a large display screen. Participants were encouraged to ask questions or share any emerging ideas on how to improve the prototype design to better meet their needs. During these discussion the participants were asked to critique the decision support capabilities of the AB–WINDEC prototype. There were a core set of questions and some probe questions. Probe questions were posed to participants to elicit their perceptions on the prototype’s design, layout, usability, and adaptability to the Alberta context, usefulness and utility. For example, participants were asked:

- “What additional features do you think would make the prototype a better decision support tool for wind farm placement in Alberta?”
- “In what ways did the prototype meet your needs, and what changes you would suggest so that it could better meet your needs?”
- “Are there any tasks you perform in the course of your work that you think is currently supported by this tool?”
- “What are the useful and not-so-useful features in the prototype?”
- “Are there any requirements you think should be considered when redesigning the prototype?”

All the sessions were audio-taped. In addition, a video recording of the large display screen was also obtained at each session. With this approach, it was possible to coordinate the audio recording of the discussions with the video recording of participant’s interactions with the large screen display. The flow of ideas was greatly improved by incorporating this visual aid. The Two
digital audio tape recorders were used in each session, to ensure that all comments were recorded clearly and accurately.

5.3.5.4 Exit survey

At the end of each focus group session, a 12-item exit survey was given to each participant to provide additional information. Some of the evaluation metrics proposed in chapter 3 were used in designing the survey questions. The survey included a five-point Likert-type scale and multiple choice questions. The questions probed for features in the prototype that participants may consider useful, or not useful, based on their interaction with the prototype. High scores represented negative perceptions; low scores represented positive perceptions.

To encourage reflection and critical observations, each survey question included feedback boxes for additional comments. This technique of feedback capture has been discussed in Bruseberg and McDonagh (2003). The purpose was to allow participants to reflect on their experiences of using AB-WINDEC, and to state their preferences in more depth than was obtainable in the group discussions.

In addition, the survey scheme was useful in capturing the opinion of focus group members who did not contribute much to the discussions (e.g., members who were relatively silent; members who are less articulate; members who do not want to reveal a different opinion or a different experience from the rest of the group; or members who did not get enough opportunity to speak during the discussions).
5.3.6 Data analysis

The digital recordings of the discussions were transcribed verbatim and analyzed using the margin coding approach proposed by Bertrand et al. (1992). The margin coding approach can be used to obtain the most thorough information on which to base analysis.

Data analysis involved one of the researchers reading and identifying themes within the data and manually coding these into appropriate categories in line with the research objectives. A second researcher working on the project then independently checked the first researcher’s interpretations. The codes and comments were then recorded on an excel spreadsheet to allow for systematic analysis. Both researchers undertook a further review of the codes, referring back to samples from the transcripts. This led to a 97 per cent agreement after the differences were resolved through discussions. In addition, quotable comments were marked for reference purposes. A similar strategy was used to analyze the words and drawings made by participants on the sheets given to them. It involved identifying recurring patterns and themes.

For the quantitative component, a database within the statistical package for the social sciences (SPSS) 21 software application was used to catalogue data from the questionnaires. The demographic and exit survey data were analyzed using simple descriptive statistics. Descriptive statistics are useful when evaluating a situation by describing important factors associated with that situation, such as demographic, behaviours, attitudes, experiences, and knowledge (Kelley et al. 2003), which applies to the present study. The data were analyzed in conjunction with additional notes and sketches that participants included in the survey. To compliment analysis of the quantitative survey data, qualitative analysis of the open-ended comments and suggestions was also conducted using the margin approach described above. Additional written comments from participants were sorted and analyzed with the rest of the data.
5.4 Findings

In this section, the findings are described according to participants’ responses and important themes that were derived from the analysis.

5.4.1 Participants’ Demographics

The self-reported demographic data of the 17 participants are reported in Table 5.1. The sample consisted of 9 men and 8 women who identified with multiple stakeholder affiliations. The resulting sample provided a reasonably representative profile of stakeholders in the Alberta wind energy industry. Indeed as many as 29% identified themselves as Regulators. The rest of the sample included Conservation groups (21.1%), Landowners (13.1%), Consultants (13.1%). Planners (10.5%), Energy Developers (7.9%), and Analysts (5.3%).

In addition, majority of the participants (30.8%) considered their primary job responsibilities as more specific to the “Evaluation and Regulation” aspects of the decision process. This was closely followed by 17.9 % that reported their primary work tasks as related to “Feedback and Reporting”. The rest were split between, Site layout design (10.3%), Data Analysis (12.8%), Advocacy and Stakeholder engagement (7.7%), Research and Data Collection (12.8%), and Feasibility, planning and policy development (7.7%).

Regarding the computer usage habits, up to 70.6% reported that they spend more than 32 h of their work week using computers or tablets. Interestingly, participants in all the focus groups indicated that they use computers or tablets regularly – for a minimum of 24 hours in a 40 hour work week. These demographic data are comparable with previous results reported in chapter 2, and shows a strong need to provide decision support to stakeholders through a computer-based system.
Table 5.1. A socio-demographic profile of focus group participants

<table>
<thead>
<tr>
<th>Gender (N=17)</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>9 (52.9)</td>
</tr>
<tr>
<td>Female</td>
<td>8 (47.1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weekly work hours using computers (N=17)</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-8</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>8-16</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>16-24</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>24-32</td>
<td>5 (29.4)</td>
</tr>
<tr>
<td>32-40</td>
<td>8 (47.1)</td>
</tr>
<tr>
<td>40+</td>
<td>4 (23.5)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stakeholder affiliation (Total responses = 38)</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landowners</td>
<td>5 (13.1)</td>
</tr>
<tr>
<td>Planners</td>
<td>4 (10.5)</td>
</tr>
<tr>
<td>Conservation groups</td>
<td>8 (21.1)</td>
</tr>
<tr>
<td>Energy Developers</td>
<td>3 (7.9)</td>
</tr>
<tr>
<td>Analysts</td>
<td>2 (5.3)</td>
</tr>
<tr>
<td>Consultants</td>
<td>5 (13.1)</td>
</tr>
<tr>
<td>Regulators</td>
<td>11 (29.0)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Primary job responsibilities (Total responses = 39)</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research and Data Collection</td>
<td>5 (12.8)</td>
</tr>
<tr>
<td>Evaluation and Regulation</td>
<td>12 (30.8)</td>
</tr>
<tr>
<td>Feedback and Reporting</td>
<td>7 (17.9)</td>
</tr>
<tr>
<td>Site layout design</td>
<td>4 (10.3)</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>5 (12.8)</td>
</tr>
<tr>
<td>Advocacy and Stakeholder engagement</td>
<td>3 (7.7)</td>
</tr>
<tr>
<td>Others: feasibility; planning; policy development</td>
<td>3 (7.7)</td>
</tr>
</tbody>
</table>
5.4.2 Experience of use

5.4.2.1 First impressions

Participants’ initial reaction to the prototype ranged from skepticism to curiosity. When prompted on their first impressions, some indicated that they were ‘still processing it, and trying to understand how it works’. A few participants complained that some pages didn’t load properly. However, most of the participants, it was observed, were quick to navigate through the prototype on their computer screens and were clearly aware that the prototype was a work in progress. Some of the participants ‘liked the modular approach’, but the general opinion on the menu tabs was divided. A good number of participants indicated that the menus were ‘intuitive’. While one participant commented that he was ‘not clear on what some of the menu tabs were set up to do’. Other representative comments were also critical of the menu tabs for ‘not really describing content’ and for not being ‘very descriptive’.

In other observations, some participants thought that there were similarities to the user interfaces of software tools like Openwind and windographer. For instance, one opined that ‘there is a lot of overlap with a sensitivity analysis tool like Retscreen’. Some participants remarked that ‘it was good to see all the relevant data sources’ and that the prototype ‘seems user focused and still enables access to all data’. Another commented that ‘a website like this could be linked to other websites that has information on wind farm development’. One participant thought it was ‘something like a white chart where you can throw things on electronically’. While another wondered if the visualization components ‘would allow noise modelling capabilities’. Several of the participants asked if they could use the application on their mobile phones. On encountering the location assessment tool for the first time, one participant commented, ‘I see that it could restrict where you put your turbines right away, and say, ‘this is a
good spot or not.’ Overall, the participants’ general first impressions could be described as positive.

5.4.2.2 Perceived ease of use

The Technology Acceptance Model (TAM) (Davis 1989), and the VADS assessment framework developed in chapter 3, provided a suitable framework for grouping and analyzing participants evaluation of ease of use of the AB–WINDEC prototype. Davis (1989) defined Perceived ease-of-use as ‘the degree to which a person believes that using a particular system would be free from effort’. Given that effort is a finite resource, an application perceived to be easy to use is more likely to have a higher acceptability.

Participants in the focus groups agreed that controllability of the menu buttons and navigability of the interfaces were important factors that influenced their perception of the prototype. One participant explained that he would not trust a system ‘whose menus are not really intuitive’. A small minority of felt that some menu labels did not clearly introduce the purpose for the menu buttons. Other participants claimed they had some experience with using similar systems, which perhaps aided their familiarity with AB-WINDEC.

A number of participants complained that the interfaces and menus were not built with ‘regular web features’ and some hoped that ‘significant improvements would be made’ in due course. For some, the prototype did not have all the requisite data they needed for analysis.

Perceived ease-of-use was also measured using four exit survey questions, three of which were designed as a five-item Likert-type questions. Participants indicated the extent of their agreement with each item on a five-point numerical scale, ranging from 1-strongly agree to 5-strongly disagree.
Interestingly, the survey question which asked participants to report the modules they successfully interacted with, in terms of clicking and accessing the interface contents, received more ‘Yes’ than ‘No’ responses (see Table 5.2).

<table>
<thead>
<tr>
<th>Modules</th>
<th>Yes</th>
<th>n (%)</th>
<th>No</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>14(82.4)</td>
<td>3 (17.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analytics</td>
<td>14(82.4)</td>
<td>3 (17.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td>9 (52.9)</td>
<td>8 (47.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation</td>
<td>8(58.8)</td>
<td>7 (41.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reporting</td>
<td>7(41.2)</td>
<td>8 (58.8)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This suggests that participants interacted easily with the prototype interface and contents. However, the modules that had the highest accessibility ratio were the Research and Analytics modules. It should be noted that the responses gathered through the exit survey questionnaires also leaned more towards a positive ratings for Perceived ease-of-use, with higher responses in the agreement scales. A summary of the results is reported in Table 5.3.
Perceived Usefulness was defined as ‘the degree to which a person believes that using a particular system would enhance their job performance’ (Davis 1989). In both TAM (Davis 1989) and the findings in chapter 3, perceived usefulness is considered an important metric that can be used to predict a stakeholder’s willingness to use a visual analytics decision support tool.

Results concerning the perceived usefulness of AB–WINDEC during the study period are reported in Table 5.4, Figure 5.4, and Figure 5.5. Participants were asked to indicate the extent of their agreement with each item on a five-point numerical scale, ranging from 1- strongly agree to 5- strongly disagree. Two other questions in the menu were multiple choice questions. Responses indicated that the majority of the participants (76.5 %) agreed that the web-based platform was a

### Table 5.3. Perceived “Ease of use” of AB–WINDEC prototype (N = 17)

<table>
<thead>
<tr>
<th></th>
<th>Easy to click through menu buttons n (%)</th>
<th>Satisfaction with menu buttons &amp; contents n (%)</th>
<th>Menu buttons were effective n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly agree</td>
<td>4 (23.5)</td>
<td>1 (5.9)</td>
<td>1 (5.9)</td>
</tr>
<tr>
<td>Somewhat agree</td>
<td>10 (58.8)</td>
<td>7 (41.2)</td>
<td>10 (58.8)</td>
</tr>
<tr>
<td>Neutral</td>
<td>2 (11.8)</td>
<td>8 (47.1)</td>
<td>4 (23.5)</td>
</tr>
<tr>
<td>Disagree</td>
<td>1 (5.9)</td>
<td>1 (5.9)</td>
<td>2 (11.8)</td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
</tr>
</tbody>
</table>

5.4.2.3 Perceived Usefulness

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useful feature to have (See table 5.4). Almost 60 percent of participants perceived the prototype as being applicable and useful to the Alberta wind farm decision process.

Figure 5.4 shows the mean score of participants’ responses to the multiple choice question, ‘What do you consider to be most useful features in the prototype?’ The visualization capability and the data management functionality were rated as very useful. The Interaction features and Task Support were flagged as not very useful. The low scores recorded for Task Support and Interaction perhaps reflect the limited development of the front-end and back-end components.

<table>
<thead>
<tr>
<th>Table 5.4. Perceived Usefulness of AB–WINDEC prototype (N = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Table Image" /></td>
</tr>
</tbody>
</table>

The perceived usefulness of AB–WINDEC was also measured with regards to certain applications and tasks. Figure 5.5 shows the mean score of participants’ responses to the multiple choice question, ‘In what ways can the prototype support you in the decision process?’ Mean values greater than 0 indicate more benefit to the participants in these applications. From the chart, it can be seen that participants considered access to information as the highest utility they would get from AB-WINDEC. This may be due to the fact that participants’ placed a higher value on the educational attributes of the system, as would be reported later in this chapter. It was interesting to note that the perceived usefulness of task support, as reported in Figure 5.5
and Figure 5.5, had similar results. This was probably because the prototype could only simulate a limited number of tasks.

![Graph showing perceived usefulness of AB–WINDEC in the Alberta wind farm decision process](image)

**Figure 5.5.** Perceived usefulness of AB–WINDEC in the Alberta wind farm decision process

### 5.4.3 Design feedback

The focus group activity provided a rich variety of comments and feedback on several aspects of the design. These are reported in this section and supported by anonymized quotes from participants.
5.4.3.1 Feedback on Stakeholder Personas

Most participants agreed with the profiles of stakeholder personas. Overall, there was an expressed understanding about the intended purpose of the stakeholder personas, which was to provide tailored login access into the prototype (see chapter 4). This disposition was captured in this comment: ‘It is OK to sign in as different categories to streamline screens and tasks that are available.’

However, some participants wanted a clearer definition of how the access and security privileges are streamlined to each stakeholder persona. They wanted to know what was in store for them when they log in using a specific persona. One participant said:

‘When I clicked on the login page as a consultant, it didn’t verify that I am a consultant or land owner. Is that going to be something that the finished product will have?’

Another participant, a land owner, remarked:

‘For now, it looks like, as a land owner, I can transfer to anybody’s page. If there are no restrictions, then I don’t know what having the different personas achieve.’

Some suggested an authentication protocol that would give each persona private access to the final web-based system and also eliminate the possible of security vulnerabilities.

‘One of the things the system has to do at the beginning is to know who I am before I am given access. What I could do is to make sure the system asks for an email address and a password code. And then the system will automatically
In the same vein, another participant observed that there wasn’t a ‘logout button’. According to this participant, ‘if you wanted to sign out or login as a different user, there is no logout button’.

The summary of the feedback was that participants easily identified with the personas developed by the design team and wanted to have restricted and persona-specific access to the prototype.

5.4.3.2 Feedback on Research Module

According to the description of the prototype’s features put forward in chapter 4, the research module, with its data integration capabilities and search engine functionality, is designed to satisfy the information-seeking requirements of stakeholders. During the focus groups, participants used the Data Manager to operate a custom data query. They were also shown how to use the search function to generate search results.

The search tool was popular with participants for its capability to facilitate basic search on wind energy information specific to Alberta. Several participants indicated that they would use the search tool to perform research tasks. One participant remarked that ‘there is value in everyone having the same access to the same data in this decision support tool’.

Participants were clear that the value of the tool as a data repository will only grow as more people upload their data. Some were particularly drawn to the feature that allows stakeholders to upload and analyze their own data. ‘I think that aspect has lots of potential and can be further enhanced with more usage’, one of the participants commented.
By far, the most pressing issue was about having the right data in the tool’s database. This refrain was echoed in the following comments: ‘You have to make sure that the tool is populated with appropriate data’.

And this, ‘Lack of data on migratory wildlife is an issue is analyzing impacts of wild life in the decision support tool’.

5.4.3.3 Feedback on Analytics Module

Many of the focus group participants expressed positive comments regarding the data viewer interface-that allows integrated visualization of data on spatial and chart views. They were particularly impressed with the capability to visualize their own data and also data drawn from the data manager in the research module. Representative comments regarding the Analytical Module included:

‘From a land owner’s perspective, I think the analytical tool is really cool. They can throw in different criteria and see how it changes the overall picture. They can also use it to analyze multiple sets of complex of data easily with the visualization component.’

And:

‘The data viewer is a useful tool for visualizing data because most of the databases in Alberta are trying to go spatial.’

However, ensuring that relevant datasets were in the data viewer was important to a majority of the participants. This view was reflected in the following comments:
‘Looking at the map data, I think it is important to ensure that the title actually match what the data is. For example, you have a visualization of migration corridors, but it is not specific as to the type of wildlife or if it is specific to wind energy.’

And:

‘The visualizations in the data viewer, for example, the migration corridor and wind speed visualizations, do not show up as a yes or no derivative. You might want to have something in there that would just say a ‘yes’ or a ‘no’.’

Also:

‘You should be using capacity factor, and not wind speed data, to visualize wind maps in the tool. Because wind speed just tells you the average.’

5.4.3.4 Feedback on Location Assessment tool

The analytical modelling capability of the location assessment tool was engaging to several participants. Many participants found the capability to apply different criteria and weights to evaluate potential locations very useful. This view was summed up by a comment from this participant who said: ‘It is useful to see there are analytical models within the system that can help us make informed decisions’.

However, there were some expressed doubts about the capability of location assessment tool to incorporate the regulatory requirements from multiple agencies. ‘It is one thing to know about the regulatory requirements,’ one participant said, ‘and another thing to successfully build it into the system’s scoring model.’
There were some specific requirements about the assessment criteria and the weights that should be used in the location assessment tool. One participant asked for ‘a flashing red panic button’ design as ‘a warning label’ for the decision bar. Other representative comments were:

‘You might want to distinguish the setbacks from specific roads. Some roads are subject to restrictions by Transport Canada, while some roads are not.’

And:

‘Using only the number of turbines is not enough. It is necessary to add the height of the turbines and the diameter of the blades because that also affects noise calculation.’

Also:

‘The criteria in the model should not be set up as a continuous mathematical variable. For example, you cannot use continuous variable to analyze potential impact on sage grouse in placement locations.’

Overall, there was an expressed need to add more data points and menu features that enhance the ‘compatibility’ of the tool.

5.4.3.5 Feedback on Design Module

Many participants were skeptical about the capabilities of the design module to optimize turbine placement layout and wind farm buildable area design. Several participants strongly felt that the current implementation of the design tool was rather out of depth for an industrial-type application. As one participant, a consultant, remarked, ‘I think the design piece is quite
ambitious. The layout design, using site-specific data, would be a lot to incorporate into the functionality of this tool.’

Similarly, participants felt that ensuring sufficient spacing between turbines required a lot of specialization, which would be a lot to ask from AB-WINDEC.

‘Building something like that would be challenging. The wind layout design process is iterative, there is a feedback process. For example, when designing a wind farm layout for noise, the noise outcome depends on the placement of the turbine. So there is a whole lot of optimization schemes that is involved. One could probably spend a career just developing those optimization schemes.’

The general consensus was that there were already more specialized tools currently being used for wind farm layout design.

5.4.3.6 Feedback on Evaluation module

Most of the focus group participants demonstrated positive feelings towards the evaluation module, but expressed doubts about its ability to support the regulatory tasks and processes. For example, one of the participants said:

‘I see that there is an attempt to simulate the multi-agency sign-off processes in the evaluation component of the tool, but it doesn’t really get there electronically. The actual process is more specific and more complicated than what this tool is offering at the moment.’
There was some consensus that the design of the evaluation module would need to incorporate more information about the stakeholders’ workflow processes before it can be integrated in the decision process. This view is mirrored in the following comments from three different participants:

(From focus group 1):

‘I would say you are much happier leaving out the evaluation section for now, but if any group is going to use it to evaluate sites or projects then you have to specialize it down to the very granular levels of interests and process.’

(From focus group 2):

‘It is good to see that the designers put some thought in the evaluation component, but it is something I think could be probably useful in the next 10 years.’

(From focus group 4):

‘For it to be part of the regulatory and approval process, it would have to be robust in a number areas.’

Judging from the comments above, it’s clear that more research is needed to understand the regulatory and approval process for wind farm placement planning applications.
5.4.3.7 Feedback on Reporting Module

Several participants made positive comments on intuitiveness of the Reporting Module and its potential to facilitate analytical communication and smoother generation of reports and charts. ‘This could save me precious hours each day,’ one participant reflected.

Some of feedback focused on the visualizations that can be generated on the reports. ‘I would like to know how charts can be inserted in the reporting forms and where it goes from there,’ one participant said. Another participant was unsure how she ‘landed on the reporting side of it’. Other participants wondered if the report interface could connect their data automatically.

5.4.4 Potential applications

As the findings reveal, stakeholders would be willing to use AB–WINDEC for a range of different purposes such as:

- Educational purposes
- Public engagement
- High-level analysis
- As a municipal risk assessment tool
- Collaboration

These findings are described in more detail in this section.

5.4.4.1 Educational tool

There was some consensus among the participants that AB–WINDEC would be more useful as an educational tool. Majority of the participants felt that the learning experience they got from using the prototype outweighs its decision support capabilities. This was a major theme that was consistently mentioned in all the focus groups. One participant had this to say:
‘This could be an educational tool to get people to a level of information where they feel that they can oppose or dispute a project on equal ground with the people that are proposing it.’

Another said:

‘My experience is that people often approach wind farm projects with a lot of wrong information. This tool can help provide basic information about the size of turbine, what the noise level would be, what threats are there to wildlife, and so on. Some of that basic information would be extremely valuable in informing the local community.’

Others comments from other groups appeared to support this view:

‘I do see value in the tool in settings where you have multiple stakeholders and multiple interests. It is easy to use and can educate the stakeholders quickly. The ability to visually represent issues, in stakeholders meetings, cannot be underestimated.’

And:

‘The public can also use it to inform themselves if they want to intervene and all that stuff. Sometimes, when you are at open houses, a lot of people may want to know more about certain issues like, for example, migration corridors for bats. So they can use this tool to play around and learn about the things they want to know more about.’
5.4.4.2 Public engagement

Participants in the groups uniformly agreed that AB–WINDEC would be a useful tool for a public engagement approach that goes beyond the usual open house mechanism. According to participants, the collaborative capabilities of the tool can support wider public participations in placement decisions in a way that significantly reduces conflict and improves a project’s outcomes.

‘Something like this is potentially valuable to people who might be impacted by wind farm development, and who do not have the resources to consult sophisticated tools or to engage consultants.’

Another participant thought that ‘it could be used as part of a big stakeholder session, in which everybody has an opportunity to provide input around a particular issues, problems, or decisions, and the system collects all the data so that stakeholders, can look at it and say, “here is what everyone is saying”.’

5.4.4.3 High-level analysis

Most participants indicated that they would use AB–WINDEC as a high level screening tool for multiple locations. Many opined that the tool would be useful to stakeholders who are considering potential development areas in the province.

‘This tool would be useful for high level analysis before you can dig into the details. For example, it would be good for preliminary high level assessments like determining access to transmission or assessing the wind resource potential at a particular location.’
Other participants felt it could fulfil a niche for a ‘*quick and dirty method to screen down about 200 potential locations to about 5*’. In this respect, there were suggestions to use the tool in analyzing issues of scale using the approach of ‘go’ or ‘no-go- areas’. One participant explained this concept further:

‘*At the high level, you are not constrained as much because all it does is show you, you know, the areas where you can or cannot build wind farms on. It is not aiding the kind of judgement that needs to be made at the end of the decision process.*’

Another participant’s comment also reflected this view:

‘*For me, I would find it more useful to help evaluate land use proposals. You know, to get a bigger picture thing.*’

5.4.4.4 Municipal-level risk assessment

Participants strongly felt that municipal authorities could use AB–WINDEC as a risk assessment tool to get a picture of where other land uses might be affected by the placement of wind farms. The general thinking was that the tool would be useful to municipal district planning authorities because they tend not to have the in-house specifications for wind farms. One participant, a planner, discussed the practicability, stating:

‘*I think there is possibility at the municipal level for a tool like this. It could be useful for risk analysis and optimization, given the various constraints and thresholds points we consider when making decisions.*’
Another participant stated, ‘Right now, it looks like it would be more useful for landowners and planners to insert their constraints’.

5.4.4.5 Collaboration tool

While reflecting on their current workflow practices, some participants suggested that AB–WINDEC can support ‘working together’, ‘ability to exchange information’, and ‘greater communication’ with other stakeholders in the wind energy industry. However, participants also stressed that research needs to be done to get to that stage:

‘It might work as a collaboration tool, but I think there is still a lot of steps and a lot of things to be covered before you get to that.’

In particular, many participants thought that the web-based nature of the tool could provide a communication channel with regulatory authorities, and may thus increase productivity and reduce the long waiting periods for applications to be approved. As one participant explained:

‘The fact is we often find it challenging getting feedback from the multiple agencies we are obligated to deal with. This would be a great tool to make things faster.’

5.4.5 Perceived issues and concerns

Participants identified a number of issues and concerns that could arise from the use of AB–WINDEC, and could prevent the tool from gaining a wider acceptability with stakeholders in Alberta. These issues include, security, data sharing, system monitoring, data quality control, and the possibility of system manipulation.

On data sharing, while participants agreed that AB–WINDEC has strong potential as a repository for integrating a wide variety of local wind energy data, the major concern was that
many beneficiaries would not be willing to upload and share their own data. One participant expressed this succinctly: ‘Many stakeholders would like to benefit from the data input by other stakeholders, but, unfortunately, I don’t expect them to show the same willingness in uploading their own data to the system’.

Similarly, some participants envisaged data proprietary issues in the future: ‘When you start getting into the site-specific factors, that’s when you start getting into the proprietary data issues,’ one participant stated.

Several participants were also worried the quality control on data and files that are coming into the system. ‘I would like to know how data is stored and monitored on the system’, was a common refrain. Some participants opined that it was becoming increasingly difficult to scale and index data from multiple data sources. ‘It would be difficult to accommodate different data types, data sources, indexes, and queries.’

The issue of security was a concern as well. Most participants felt that the security of the system needs to be addressed, stating, for example, some ‘concerns with the issues of confidentiality and security in the system’. Indeed, some participants in the focus groups expressed concerns about the possibility of system manipulation: ‘I would be worried about the proponents gaming the system and shoe-horning their projects into the best score.’

Similarly, some participants made the argument that AB–WINDEC does not have a monitoring system, and that certain controls are not in place. One participant said: ‘I am wondering who should be monitoring the system. Is it a government or is there one person who takes it on? Or is there going to be a private company monitoring it.’

Several participants thought the system design was well-intended, but that the prototype was rather ‘over-ambitious’ and may not fit into the decision process. One said:
‘I am not sure it would fit for actual regulatory mechanism, because different agencies have different things they use for their assessments when making decisions on placement locations. Sometimes the things they look for are subjective.’

Some participants felt that AB–WINDEC does not have the sophisticated modelling capability that is required in the decision process. More so, given the huge and complex data that has to support the modelling functionality

5.4.6 Participant’s wish list

The focus groups were able to suggest a number of improvements to the current design. These included:

5.4.6.1 Enhance the stakeholder persona login protocol

The point was made by a number of participants that the persona login approach should allow for stakeholders’ data, weightings, models, criteria, designs, etc. to be saved, retrieved and resumed at a later date.

For the tool to be relevant for project application and submission, participants suggested that wind farm planning submissions should be assigned a unique number. It was also recommended that stakeholders who use the tool should be allowed access to only documents that pertain to their stakeholder personas.

5.4.6.2 Enhance noise modelling capabilities

Some participants emphasized the need to develop the prototype’s noise modelling capabilities, in view of the fact that the turbines are laid out mostly with regards to noise
constraints. One participant recommended using the ‘doubling of distance technique’ to estimate distance between wind turbines and noise receptors, explaining:

‘At the screening level, getting the system to gauge the distance between the turbines and potential receptors might be suitable proxy way to get around the noise modelling challenges.’

Another participant added:

‘You can get noise data from manufacturers. In AUC rule 12, there are various calculations you can use to propagate noise to the potential receptors.’

Other participants simply wanted the noise modelling to analyze impact on wild life locations, for instance: ‘I would be interested in using the tool to understand more about low-frequency noise and how it can affect near tropical migrants that might be nesting.’

5.4.6.3 Support assessment of transmission lines

Many participants were of the opinion that the prototype can be optimized to support assessment of transmission lines and access to transmission lines. Some wanted the capability to visualize utility corridors and transmission lines. One of the participants articulated it in this comment:

‘Existing tools tend to focus on other issues like wildlife, noise, etc., but not on transmission. So I think this tool would really be useful as pre-assessment tool for high-level analysis of transmission availability and options.’
5.4.6.4 Develop a financial module

Focus group participants stated that the biggest technical enhancements in the prototype should come the form of financial module that can analyse the economic opportunities for land owners and local communities. This module, according to several participants, should also have the capability to calculate potential carbon credits from wind energy development. As one explained:

‘The financial model in the tool should reflect the dollars per megawatt hour analysis of siting a wind turbine. It should also have the capability to correlate the variable power price with predominant wind regime. This would allow stakeholders to optimize the price discount relative to the pool price.’

5.4.6.5 Develop a “social value” module

Several participants were interested in how to bring the social values of communities into the wind energy decision process. Participants wanted to see a social value module that is designed to support stakeholders’ considerations of potential impacts of placement locations – to ensure that wind energy development activities have positive effects on people’s values. This wish is reflected in the following comments from different participants:

- ‘We would like to have a tool that brings the social value into the discussion around wind energy development.’

- ‘It would be interesting to see how this tool can connect to the social value and community level of the decision process.’
- ‘Part of what I envisage for the assessment part of the tool is the capability to allow the people to pick from a list of social considerations that influence where development can happen or priorities that reflect elements that people want to preserve in a landscape.’

The general opinion was that having a social module would answer some broader questions surrounding some of the placement issues and would help ensure fairer decision outcomes.

5.4.6.6 Upgrade the location assessment tool

Several participants suggested that the location assessment tool within the analytics module should be upgraded to a standalone module. It was generally accepted that a fully optimized location assessment module can help stakeholders find the best land use solution if based on setbacks, constraints and indicators that are already used by stakeholders. As one participant indicated: ‘It may be useful to work with stakeholder groups to come up with the criteria and the indicators they want, and then you can go away and incorporate it into the location assessment tool.’

Nearly everyone wanted the ability to optimize placement locations using their own values and criteria. For example, one participant thought it would be interesting to model the optimal number of turbines that can be for a particular location, using the location assessment tool:

‘In the location assessment tool, it would be useful to have a feature which can tell you, that to optimize a particular site you would need a certain number of turbines.’
Some participants also wanted the location assessment tool to be connected to the data viewer. One participant said: ‘I think it would be nice to have a functionality where you can export the data and criteria you analyzed on the location assessment tool to be visualized in the data viewer.’

In addition, some participants suggested that the ‘decision bar’ feature, in the location assessment tool, should provide more detail when providing assessment scores on a selected locations.

5.4.6.7 Adopt a tiered system

Participants suggested a feature similar to the U.S. fish and wildlife wind energy tier guidelines, where the decision support system is broken into tier system. This participant emphasized the importance of this approach:

‘The constraints in each tier will automatically apply to any potential location you are reviewing for wind farms. When you get past one tier, you move to tier 2, tier 3 and so on, which is like what you have in AB-WINDEC, moving from research to analysis to design and then to evaluation. When you get to the end, you are at the stage of approvals.’

5.4.6.8 Use a scaling approach

Some participants felt that incorporating a ‘Scaling’ technique in the tool can be useful in categorizing some of the placement issues. One participant familiar with the technique shared:

‘You can put wind resources areas on a regional scale which shows areas where there are wind and areas where are no wind. Coming down to the
municipal level, you can also create scale of ‘go’ and no-go areas. And you can use a scale all the way down to the site specific issues. This way you can get a better perspective of what the issues are on a regional, provincial, or municipal scale.’

The scaling technique was also suggested as a way of enhancing the educational attributes of the prototype.

‘If the tool can work on a provincial, regional, municipal, versus site scales, then I think it can meet the educational needs of stakeholders, which would, in turn, feed into the decision support process.’

5.4.6.9 Enhance data integration capabilities

Some participants wanted to implement more rigorous data integration procedures in the system. For example, some argued that specifying the acceptable data formats will enhance quality control on data going the system. One illustrative comment was:

‘I suppose there is a way to specify that data being brought into the system should be in a specific coordinate system. I just mean that if that is a requirement of the system, then one should be more explicit in saying that, you know, “make sure your data is in a specific coordinate system”.’

The wealth of ideas identified through analysis of both qualitative and quantitative sources of data reflects the majority of views and range of interests among wind energy stakeholder groups in Alberta. This is one step forward in the research to provide contextual information on how to create tools that can fit the needs of stakeholders and the social contexts they operate in.
However, it also calls into consideration a discussion on how the data and ideas can be used to generate concrete design concepts and incorporated into novel interfaces that enhance the experience of using the product. These issues are discussed in the next section.

5.5 Discussion

The AB–WINDEC prototype was evaluated in four focus groups to determine how well the prototype met stakeholders’ decision support requirements. The nature of the contributions during the focus groups confirmed that the participants had a thorough understanding of wind farm placement and decision support issues. As noted previously, it was important to accurately capture the opinions expressed by participants in order to improve the AB–WINDEC prototype design. Careful and systematic analysis of the discussions provided insights on how the prototype was perceived by the focus groups. The significant insights are discussed below.

5.5.1 Potential challenges and barriers to acceptance

Analysis of the focus group data identified some major barriers that may likely affect the adoption and use of AB–WINDEC by stakeholders in Alberta. These were:

5.5.1.1 Current design scope is too broad

There was consensus that the prototype was ‘ambitious’. Several participants expressed concern that some aspects of the tool, namely Design, Evaluation and Reporting modules were ‘doing a little too much’, yet without offering significant advantage over existing tools. Nevertheless, several insights can be drawn from this. First, the assertion points to the benefits of adopting a modular design strategy. Participants were able to appreciate each module as independent sub-divisions of the system, while recognizing the separate functionalities they
provide. With this interpretation, they were able to compare the tools they currently use with the capabilities offered in each module. What can be garnered from this is that attaching unwanted components to AB–WINDEC could lead to lower acceptance and lower integration levels. Furthermore, reducing the design scope makes it easy to focus design efforts on the modules that stakeholders want and to optimize those capabilities accordingly.

5.5.1.2 Inadequate access to data

When discussing the challenges to accepting AB-WINDEC, participants did reflect on the lack of availability of requisite data sets for decision-making at regional, municipal and provincial levels. There are proprietary and ‘format’ limitations that prevent the availability of several datasets in the prototype. Improved access to data can be accomplished by developing AB–WINDEC as a formidable data repository. Nevertheless, the seeming lack of trust among stakeholders who are in competition (also see chapter 2) for placement locations appears to be a big impediment. Also, the process of incorporating datasets into a decision support system requires data to be modified into a standard format that can be used by the system. This is because of the vast quantity of data come in different shapes and sizes. One participant suggested that if stakeholders accept specific standards for data integration, then convergence of data formats could be easily achieved.

5.5.1.3 Security

There was a clear recognition, in all the focus groups, that security was an important issue with AB-WINDEC. Participants were keen to know what measures were in place to ensure reliability and confidentiality of data in the system, and how to protect the system from manipulation. Access to data, for example, is made more difficult by the stakeholders’ insistence
on having effective security protocols in systems. Participants felt that the lack of stringent verification procedures may discourage the real stakeholders from using the system. This kind of online interaction, according to participants, requires technology that is secure.

5.5.1.4 Usability

In the discussions, some of the participants felt the interactions with the menu buttons lacked specificity, even after receiving explanations on how the different menus were designed to work. Poor usability, it was gathered, may discourage stakeholders from incorporating the tool in the decision-making process.

5.5.1.5 Poor presentation of complex information

Some participants were concerned that many of the menu buttons and interfaces do not offer simple ways of accessing complex information, and that this may lead to limited access to relevant material. This calls to mind the need to design the interface with a clear and consistent conceptual structure, and to link the menu content to interactive visual cues that are familiar to stakeholders in Alberta. The major points that may be considered in this regard are simplicity, clarity, distinctiveness, and emphasis.

5.6 New Requirements

While existing requirements, such visualization, and analytics, were emphasized, several new requirements that can enhance the capability of AB–WINDEC were also suggested. These new requirements were:

- Enhance the persona login protocol
- Enhance noise modelling capabilities
- Support assessment of transmission lines
• Develop a financial module
• Develop a “social value” module
• Develop a location assessment module
• Adopt a tiered system
• Use a scaling approach
• Enhance data integration capabilities
• Enhance interface interaction capabilities
• Emphasize educational features
• Enhance usability
• Reconsider the design scope

These requirements can be classified into two broad categories: usability requirements and decision process requirements. The latter can be described as social requirements that seek to align the tool with the wind farm decision process in Alberta. While the usability requirements evolve as technical requirements that are used to deliver the decision support requirements. This direct interaction between the social and technical requirements attests to the need for a socio-technical approach to design of decision support tools canvassed in this work.

5.7 Value propositions

It is important to note that applications often projected as useful, from a designer’s point of view, might not be regarded in the same light by the people on the receiving end. Participants offered several potential applications where AB–WINDEC can bring greater value to the wind farm placement decision process. However, the most obvious application lies in enhancing the ‘Educational’ capabilities of the tool. The results suggest that AB–WINDEC can provide better
decision support when deployed as an educational tool. It seems logical that participants would appreciate an educational application because it permits a simple learning approach and a more accurate understanding of the complex decision issues. In this sense, other application examples provided by participants (High-level analysis, Collaboration etc.) showcase the versatility of AB–WINDEC in situations where stakeholders would most likely need decision support. Adapting the prototype to these applications will likely increase its effectiveness and a greater chance of stakeholders’ buy-in.

5.8 Refining the design

One of the benefits of conducting the focus groups is that participants yielded interesting insights on ways to improve the prototype design. Additional feedback from participants pointed out the value of tailoring new design concepts to participants’ wish list. Further design activities should develop a greater understanding of how to apply them to the design. For instance, one of the objectives should be to agree on and collect what high-level information should be incorporated in the prototype.

5.9 Limitations

The limitations of this study are significant and should be acknowledged. In the first place, recruitment of participants was a major hurdle for this research, given that specific stakeholder profiles were required in the inclusion criteria. Consequently, the study was based on a convenient sample of 17 stakeholders, which may not be considered statistically significant. However, this limitation is addressed by the purposeful approach and inclusion criteria used for the sampling. Thus, the final sample of participants represent significant groups in the targeted stakeholder community, and participants tend to speak on behalf of their groups. To minimize
selection bias, participants were randomly assigned to the 4 focus groups from the pool of 17 participants.

There was invariably a very large amount of data, mostly on audio tape and questionnaires, supported by notes and sketches, which presented a challenge in reporting the findings. It is relatively easy to bias the final outcome by inclusion or exclusion of key statements, by choosing points of view, or by taking comments out of context. However, to reduce the risk of drawing incorrect conclusions, quantitative analysis methods were used in tandem with the rigorous qualitative analysis procedures.

Third, data from the surveys provided new information that may not have been discovered in a traditional focus group study. The usefulness of the survey scheme lay in its ability categorize self-reported ratings of participants and to provide some structure to the analysis. Descriptive statistics offered a more contextual, easily understood analysis of the data. While other statistical methods may be useful in making wider-reaching inferential analyses, the efficiency of the descriptive statistics approach was sufficient for the scale of study and the study goals. Nevertheless, it is important to note that the numbers used in the results do not convey the impression that the distribution can be projected to a wider population of stakeholders. It is not the intention of this study to generalize.

5.10 Future Work

The data from the focus groups will be used to generate further design concepts. Based upon this results, and results from the previously reported research, a high fidelity prototype of AB–WINDEC needs to be re-designed and developed. Further studies need to be performed to evaluate how effective the re-designed AB–WINDEC prototype is in supporting stakeholders in
identifying appropriate placement locations for wind farms in Alberta, and the quality of the interface relative to the usability requirements of stakeholders.

Finally, because the focus groups were mostly done on computers and laptops, the evaluation did not comprehensively address the issue of interoperability in multiple devices. This may be a topic of consideration for future research.

5.11 Summary and Contributions

This chapter provided compelling feedback from wind energy stakeholders regarding the proof-of-concept AB–WINDEC web-based decision support tool. The results indicate how well the prototype was perceived by stakeholders and also show the key concerns that must be addressed if the system is to realize its full potential.

Although there are still hurdles that must be crossed, the results of this study has increased current understanding of how stakeholders interact with tools and what is required to effectively support them in making appropriate wind farm placement decisions. The findings have also provided useful design knowledge that would likely be relevant to the integration and use of AB-WINDEC.

For example, findings from this research provided additional requirements and guidance for a tool that will fit more closely stakeholder’s needs. Many of the participants commented on the need for better layout features, educational content, analytical capabilities and ease of use. These contributions can be used to improve the prototype design. Given the findings, it may be worthwhile to prioritize certain aspects of the prototype in redesign process – specifically the modules that support educational learning, data integration and high-level analysis.
References


knowledge over the Internet. IEE Comput 4:54–62


Chapter Six: Setting a New Template for the Design of Effective Decision Support Tools for Wind Farm Placement Planning

6.1 Revisiting the research context and objectives

The research in this thesis was motivated by a unique set of challenges that impede the development of effective decision support tools for wind farm placement planning in Alberta namely, lack of coverage and integration of place-specific issues, non-incorporation of stakeholders’ decision support requirements, emphasis on the technical capabilities in existing tools rather than human needs, and a lack of framework that defines the scope, structure, design, and implementation and evaluation process of decision support tools.

This thesis sought to address the following objectives:

I. Identify the contextual issues that influence decision-making in wind farm placement planning in Alberta.

II. Identify the stakeholders’ decision support requirements for wind farm placement planning in Alberta.

III. Determine the attributes of useful decision support tools through state-of-the-art investigation and recommend criteria to guide design and evaluation of decision support tools applicable to wind farm placement in Alberta.

IV. Develop a framework that incorporates I, II, and III, and lays out specifications for a wind farm placement decision support tool in Alberta.

V. Design and implement a proof-of-concept prototype decision support tool that integrates the relevant information and analysis tools to support stakeholders in identifying appropriate placement locations for wind farms.
VI. Evaluate the utility and effectiveness of the prototype as a tool in wind farm placement decision-making with stakeholders to assess how well the prototype meets their functional goals and usability needs.

The discussion in this chapter shows how these objectives were addressed and synthesizes the major conclusions of the thesis. After highlighting a number of design implications, a list of recommendation for future research is provided.

6.2 Synthesis of findings and contributions

This thesis has presented a real-world application of the socio-technical approach to the development of a decision support tool that is useful for wind farm placement planning in Alberta. The work in the thesis investigated the complex interaction between social and technical aspects of this intervention by highlighting the nature of decision support required by stakeholders and the challenges in designing, implementing, and integrating the proposed tool. Findings in the thesis has provided insight into these challenges and opportunities that are inherent in the design and development of the prototype tool. Figure 6.1 shows a visual flow chart of the main research themes in the foregoing chapters.

A key theme that emerged in this work is that successful implementation of an effective decision support technology depends largely on having a clear understanding of the interplay between the technical and the social requirements. This supports my thesis in chapter 1. In fulfilling the research objectives, the findings have led to a number of contributions. This section integrates the findings and how they addressed the research objectives.
6.2.1 Chapter 2: Decision support requirements for wind farm placement planning in Alberta (objectives 1 and 2)

From a methodological perspective, findings from chapter 2 demonstrated the usefulness of mixed research methods in providing an in-depth understanding of the issues related to wind farm placement decisions. The qualitative and quantitative data (although not statistically significant) were integrated during the analysis to allow for thematic and descriptive statistical analysis of both data types together. The approach used in this study contributes to the repertoire of promising analytic strategies for mixed-methods research studies.

Findings from chapter 2 also highlighted stakeholder requirements that could perhaps lead to more effective decision support when planning the placement of wind farms in Alberta. The findings provided key insights into the complex cause and effect relationships between
placement issues and decisions. This process allowed us to understand the experiences that stakeholders seek, thus increasing current knowledge on how to support them better in their decision tasks.

One of the main contributions from this chapter was the categorization of stakeholders into distinct stakeholder personas driven by different goals and attitudes, and interests, with clear motivation to seek information that align with their interests. These stakeholders personas where further used as design tools in the making of AB-WINDEC. We found that focusing on features that can incorporate the needs of these stakeholder personas into the decision process was an important factor in designing tools that will be useful to stakeholders.

The nature of tasks that currently go into the wind farm placement decision process in Alberta was also identified in this chapter. The process of these tasks, it was found, were semi-structured and inter-dependent. Five task categories were established, namely, Research, Analysis, Design, Evaluation, and Reporting. The results also suggested that most of the tasks are data-driven, such that stakeholders conscientiously look for data resources required to accomplish their tasks.

Furthermore, the findings established a strong link between the data requirements and issues that relate to wind farm placement planning. While data requirements for decision support tools have been considered in other domains, no research has been conducted on the specific database requirements for wind farm placement decision support in Alberta. These findings suggested that the proposed decision support tool can be designed to support the tasks and data requirements. Specifically, these findings implied that the task work flow should align with the data in the model and interface design.
Further investigation in this chapter discovered new insights into how stakeholders in Alberta might use the proposed tool in the decision process. For instance, participants indicated a preference for certain usability features which we interpreted as desirable functionalities in the proposed tool. There was a strong indication for a tool with a modular functionality, analytical modelling and interactive visualization capabilities. While the existing tools have their uses, the interview data suggested that stakeholders cannot always find the capabilities they require to perform their work tasks in a single decision support tool. Consequently, they tend to use several tools to perform their tasks.

Overall, the work in this chapter fulfilled the first two research objectives and established a case for designing effective tools that are adapted to the socio-technical context of the wind farm placement decision process in Alberta. Taking these findings together, we developed a list of recommendations that focus the design choices on the stakeholders’ requirements.

6.2.2 Chapter 3: Towards a product design assessment of visual analytics in decision support applications: a systematic review (objective 3)

Results from Chapter 2 implied that the proposed decision support tool should have a visual and analytical character. A review of the visual analytics agenda as discussed by Thomas and Cook (2006) brought to view the following requirements:

- analytical reasoning techniques that let stakeholders obtain deep insights that directly support assessment, planning, and decision-making;
- visual representations and interaction techniques that support the stakeholder in understanding large amounts of information and missing relationships that might lead to deeper insights;
- data representations that convert all types of conflicting and dynamic data in ways that support visualization and analysis;
- techniques to support presentation and dissemination of analytical results to communicate information in the appropriate context to a variety of stakeholders.

Clearly, the research and development agenda for visual analytics applies to the technical and social considerations that are common in the wind farm placement decision context in Alberta. However, although it is conceptually simple, the application of visual analytics in the development of decision support tools is laden with considerable challenges. Because it is an emerging field, one of the most challenging research gaps in visual analytics is the definition of standard attributes to assess and evaluate the performance of visual analytics tools. While some research has been done within the visual analytics community in the past, the degree to which the attributes have been defined and accepted by the community was quite limited. The idea was to begin an empirical discussion of what attributes and measurement metrics should govern the design, implementation and evaluation of visual analytics tools. The idea began with a simple question: what are the attributes of good visual analytics decision support (VADS) tools? If we think of visual analytics tools as technological products that will serve human and societal needs, how can we begin to develop them to achieve this purpose?

In Chapter 3, a systematic approach was developed to define these attributes and their underlying metrics in the context of VADS tools. The theoretical concepts behind the attributes were grounded in the principles of human-system interaction (ISO 9241-110 2006), experience design, product design, and visual analytics.

Chapter 3 also proposed a framework of organizing the design process of VADS tools, in which we classify AB-WINDEC, to ensure that the effectiveness of the tools can be measured in
standardized ways. This framework was then used to evaluate and synthesize the empirical findings in visual analytics literature from 2006 to 2012.

The findings also emphasize the need to streamline the design process in a manner that reflects the goal of enhancing the experience of using VADS tools. Furthermore, the results indicated a general consensus that the evaluation of a VADS tool should reflect its ability to support the decision-making process, and at the required scale. Additionally, there was a clear indication that using the attributes and metrics proposed in the framework would increase stakeholder involvement and satisfaction.

The results of these investigations highlight the utility of applying a product design approach to the design of AB-WINDEC. The product design perspective, as described by Archer (1974), is the efficient and effective generation and development of ideas through a process that leads to new products. The findings from chapter 3 broadly demonstrate that useful VADS attributes, and their underlying metrics, can be used in measuring the impact of VADS tools, their effectiveness in improving decisions, as well as their likely rate of adoption in the wind farm placement decision support domain.

In summary, the framework of attributes proposed in Chapter 3 offers a way of organizing the design process so that the effectiveness of the VADS tool can be measured and improved. In a developing field such as visual analytics, this understanding is beneficial because it illustrates the benchmarks that will serve as the foundations of the field as it matures.

6.2.3 Chapter 4: A prototype visual analytics decision support tool for wind farm placement planning in Alberta (objectives 4 and 5)

A major contribution in Chapter 4 was the development of a conceptual socio-technical framework and a proof-of-concept prototype based on stakeholders’ decision support
requirements in Alberta. The framework laid out the specifications and dimensions for the proof-of-concept prototype and has helped to build an understanding of the interconnections between the social and technical requirements of a decision-making process. From a product design perspective, Chapter 4 demonstrated a new approach of translating requirements into concrete design ideas and functionalities. The resulting prototype, AB-WINDEC, responds to the need of adapting the decision support tool to the decision process, incorporating the main decision issues, handling data, and engaging stakeholder background knowledge and preferences. This contribution opens up the design process to a world of creative alternatives in integrating and visualizing place-based information to support analysis related to determining suitable locations for wind farm placement planning in Alberta.

Another contribution from Chapter 4 is the novel approach in which the scope, structure, design, and implementation process of the AB–WINDEC prototype were defined. The architectural design of the proposed system was developed and it incorporated the requirements proposed in the socio-technical framework. In addition, the chapter provides recommendations on how iterative prototyping methods can be applied to provide a structured approach to visual design.

The AB-WINDEC’s set of functions were designed and implemented as a fit-for-purpose tool for wind energy stakeholders in Alberta. The prototype side-stepped many of the common shortcomings of existing tools by focusing on the needs of stakeholders. This feature is shown in the simple design, automated data flow, task-oriented interface, web-based platform, multiple data displays and interactive visual analytics.

Furthermore, Chapter 4 established that AB–WINDEC can be run by a combination of data-and-model-driven framework, thus bridging the gap between data-driven and model-driven
decision support tools. For example, a mathematical model was developed to run the back-end analytical calculations *Location Assessment* tool in AB-WINDEC. The mathematical model and data-driven model are designed to support the wind farm placement analytical process in various ways. Accordingly, stakeholders can use AB–WINDEC to visualize multiple data sources, statistical analysis, and to optimize scenarios for predictive land use simulation. These two approaches, the data and model, complement each other effectively, leading to a dynamic and more accurate data analysis. The data-driven and model-driven combination also enhances the visual analytics approach by allowing stakeholders to rotate their views on the data, changing the relationships in order to get more detailed insight into land use trends and identify potential issues and opportunities.

Chapter 4 also demonstrated, for the first time, how iterative prototyping techniques, with progressive degrees of fidelity, can be successfully applied to support design of a visual analytical decision support tool for wind farm placement planning. The transitions from the conceptual design stage to the medium fidelity decisively enhanced the design and implementation of AB-WINDEC.

These approaches and features, as the expert appraisal show, served the purpose of enhancing the usability, ease of use, and usefulness of AB–WINDEC to stakeholders, which is the basic tenet of socio-technical approach to decision support proposed in this thesis. Overall, the chapter addresses the objectives 4 and 5 in the thesis.

6.2.4 Chapter 5: Design evaluation of a prototype decision support tool for wind farm placement planning in Alberta: Results from a focus group study (objective 5)

Phase four in the research was a focus group activity to get stakeholders’ feedback on the concept and prototype design of AB-WINDEC. Based on the results of previously reported
requirements in chapter 2, the assumption was that evaluating the functional prototype in focus
group settings will help determine how well the design matched the requirements of
stakeholders.

There was certainly a range of interesting opinions and recommendations from stakeholders
who served as participants. Some of the recommendations that can be carried forward to the next
stage of the development of the prototype tool were:

- Enhance the persona login protocol
- Enhance noise modelling capabilities
- Support assessment of transmission lines
- Develop a financial module
- Develop a “social value” module
- Develop a location assessment module
- Adopt a tiered system
- Use a scaling approach
- Enhance data integration capabilities
- Enhance interface interaction capabilities
- Emphasize educational features
- Enhance usability
- Redesign the scope of the tool

The findings provide significant insight into the expected social and technical attributes of
the proposed tool. As a proof-of-concept, the focus groups helped to determine if the prototype
was a viable product concept. In addition, the results from the study contributed to the body of
knowledge on the perceived utility of visual analytics decision support tools in a wind farm
placement decision-making process. These findings addressed objective 6 in the thesis, and also contributed to a deeper understanding on how to adapt the design process of a decision support tool to the stakeholders and the intended use of the tool.

6.3 Implications of findings

Every chapter in this thesis has been a movement towards knowledge. The thread of this knowledge is aimed at providing a consistent, reproducible process for decision support and enhancing communication between different stakeholders.

While it would be premature to arrive at detailed and measurable conclusions on what the implications of the findings from this research may be, however, certain implications can be easily deduced.

6.3.1 Implications for wind farm planning and decision process in Alberta

The results of this study are particularly important from the standpoint of industry and government agencies involved in the placement of wind farms in Alberta because they suggest that providing adequate decision support for the placement of wind farms requires a clear understanding of the issues at hand, the positions of different stakeholders involved, the trade-offs to mitigate the potential impacts at certain locations. However, the results of this study also suggest that it might be premature to view the capabilities of the prototype as adequate to support decisions that are more widely accepted by the public at large. Rather, it may be prudent to view the benefits of AB–WINDEC in terms of its potential ability to help stakeholders make higher quality decisions that are the product of more widely accepted decision process. This conclusion suggests that AB-WINDEC, based on the results from chapter 5, may be best regarded as an
educational tool for increasing the knowledge of stakeholders about the merits and demerits of potential placement locations.

6.3.2 Implications for usability and perceived usefulness

The discussions in chapter 5 demonstrate that stakeholders would be keen on using the information and resources available in AB-WINDEC. The results also indicate AB–WINDEC was generally perceived to be useful in providing relevant information, enhancing situation awareness, and facilitating data analysis. However, while these results show an encouraging response from stakeholders, more progress can still be made by addressing the usability and utility concerns raised by participants in chapter 5.

6.3.3 Implications for VADS design and evaluation

In the light of work done in chapter 3, we have gained more understanding of the attributes that can enhance the design, implementation and evaluation of visual analytics tools. This is especially important when considering the usability and usefulness of VADS tools that are designed to support decision-making in complex domains like wind farm placement planning. These trends imply that future designs of visual analytics decision support tools can now be based upon strong methodological standards and human experience design principles.

On another level, this research has shed new light on how a visual analytic and place-specific decision support tool can be designed to match the socio-technical requirements of stakeholders involved in wind farm placement planning in Alberta. While the modelling components all contribute to evaluation of potential placement locations, the visual analytics character of the AB–WINDEC potentially offer stakeholders the ability to understand the conflicting land use issues, identify alternatives, and acquire knowledge needed to make informed decisions.
6.3.4 Implications for refining the design of AB-WINDEC

As is evident from the "wish list" drawn by the focus groups in Chapter 5, several other requirements that influence the success and acceptance of decision support tools in the wind farm planning process in Alberta have been brought to light through this research. Further requirements can provide guidance for the development of more effective planning support tools. The new requirements highlight the socio-technical nature of the AB–WINDEC as a decision support technology. To guide the project and to ensure a final product with functionalities that matched the requirements of the different stakeholders would require a closer engagement with stakeholders. However, while the improvements on the tool can appear feasible, it is noteworthy to ensure that stakeholders’ expectations are properly managed so as to avoid disappointment that would create barriers to integration and use.

6.3.5 Implications for stakeholder engagement in the wind farm placement decision process

Generally, findings from this research are relevant in science, policy, and management, dealing with critical issues of technology change and its impact on society, land use, and environmental management. With the increasing involvement of stakeholders in wind farm planning processes, it is expected that decision-making would become more interactive and complex, demanding interactive and visual-based tools to manage it. The concept of AB–WINDEC is based on integrating different interests and views of multiple stakeholders. The systems model is designed to facilitate participation and collaboration, and can thus support different phases of the decision process.
Consensus from the focus groups indicates that prototype can be adapted into an educational tool, which may increase the number of stakeholders who could use it and make decisions about wind farm placement.

In this context, findings from this research can help close the gap between the conflicting stakeholders’ interests, regulatory constraints, increase legitimacy and responsibility in land use decisions, thus improving the chances of achieving mutually acceptable trade-offs.

Even if trade-offs are not achieved, stakeholder interaction and collaboration, facilitated by AB-WINDEC, may produce net benefits, simply by the information shared (Jurgen 2006).

6.3.6 **Improving the knowledge creation for decision support**

Steiger & Steiger (2007) suggested an expanded role for decision support tools in the 21st century – which is the creation of new knowledge applicable to the decision domain and the learning and understanding of that new knowledge by stakeholders.

One of the key findings from this research was the elicitation of decision support requirements of stakeholders in the Alberta wind energy domain. I consider this, and other findings developed from each chapter of the thesis, a step forward in the advancement of knowledge because they add new information and resources to decision support in the Alberta wind farm placement domain. Clearly, the knowledge can be used to inform both the product of the design (i.e., AB-WINDEC) and the process of the design (the methods used to develop AB-WINDEC).

6.4 **Reflections on Methodology**

A set of research methods have been used in this thesis; each being appropriate for different aspects of the research study. Table 6.1 presents the main research methods used.
What binds together the research methods in Table 6.1 is the *Research and Development* methodology. The *Research and Development* methodology belongs to the formulative type of research where scientific knowledge is used to produce ‘...useful materials, devices, systems, or methods, including design and development of prototypes and processes’ (Blake 1978). By using this approach I have been able to enhance knowledge and develop a prototype decision support tool for wind farm placement planning in Alberta.

In chapter 2, the research methods (semi-structured interview, questionnaires) were useful in identifying the decision support requirements, and in addressing the knowledge gaps from which the thesis was formed. Knowledge gained from using these methods became the basis for expanding and continuing the research in the subsequent chapters.

A proportion of the research work done in chapter 3 involved discovery of new knowledge in the fields of visual analytics and product design. By providing a summary of all the studies addressing the question of ‘useful attributes’ of visual analytics decision support tools, the systematic review in chapter 3 allowed a range of findings relevant to the research objectives. The content analysis methods helped to establish the validity of the findings – if these were generalizable across populations, real-world settings, and design variations.

In chapter 4, the *Research and Development* methodology was used to demonstrate the feasibility of the proposed system architecture. Also, the methods used in designing and implementing the prototype system provided insights into the evolving design concepts, the application of the socio-technical framework, and the range of design approaches. Furthermore, the expert appraisal method facilitated a significant improvement in the design of the prototype by detecting critical problems and providing priorities for evaluation with stakeholders.
In chapter 5, focus group method, as part of the *Research and Development* methodology, was designed as a combination of research methods, including survey questionnaires and blank paper techniques, to evaluate the effectiveness of the prototype design for its intended purpose. These methods helped in gaining stakeholders’ impressions and perceptions about AB-WINDEC, and also in stimulating design ideas that would be reflected in the new version of the prototype.

**Table 6.1. Thesis Research Methods**

<table>
<thead>
<tr>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-structured interview</td>
</tr>
<tr>
<td>Questionnaires</td>
</tr>
<tr>
<td>Content analysis</td>
</tr>
<tr>
<td>Focus groups</td>
</tr>
<tr>
<td>Qualitative analysis (Inductive and Margin)</td>
</tr>
<tr>
<td>Quantitative analysis (Descriptive statistics)</td>
</tr>
<tr>
<td>Modified blank page technique</td>
</tr>
<tr>
<td>Systematic review</td>
</tr>
<tr>
<td>Prototyping</td>
</tr>
<tr>
<td>Expert appraisal</td>
</tr>
<tr>
<td>Bibliometric research techniques</td>
</tr>
<tr>
<td>Pilot study</td>
</tr>
</tbody>
</table>

Individually, the methods used in the thesis have their own strengths and weaknesses when viewed in terms of Generalizability, Precision, and Realism, as defined by Mcgrath (1995). However, because they were mostly used in combination, the individual strengths of the methods were maximized and the weaknesses minimized, and thus provided greater validity and understanding of results. Moreover, the methods used in thesis were also designed to limit bias.
and, hopefully, will improve accuracy and reliability of conclusions. For these reasons, there is a strong sense of justification that the Research and Development methodology was effective in addressing the research objectives.

6.5 Future Directions

A number of unresolved issues pertaining to the development of AB–WINDEC were identified in the thesis. I recommend that future research should concentrate on advancing knowledge in the following thematic areas:

6.5.1 Fidelity

At this stage in the development of AB-WINDEC, only two levels of fidelity – low fidelity and medium fidelity – have been developed. The present adaptation of the medium fidelity level, with detailed information about navigation, functionality, content and layout, is rendered in schematic (“wireframe”) or approximate form. Due to the huge costs, expertise, and efforts required (Engelberg and Seffah 2002), developing a high-fidelity prototype is beyond the scope of this thesis. Nevertheless, it is necessary to continue the development to the high fidelity prototype using the methods suggested in this work. An empirical evaluation of the high fidelity AB–WINDEC prototype is also recommended, and should involve software engineers, usability specialists, and Web designers.

6.5.2 Incorporating new requirements and design concepts

Future research should seek to incorporate the new concepts developed in Chapter 5. For example, based on the findings in chapter 5, the educational and scaling features proposed by participants needs to be designed in the prototype. Furthermore, in the focus groups, there was a strongly expressed desire by stakeholders to jettison some of the modules, as presently
constituted, because these did not capture their processes effectively. These modules, for example the evaluation and design modules, should therefore be re-purposed through research that will study the task processes and the contextual requirements of the various regulatory agencies that deal with wind farm placement applications in Alberta. Ultimately, further studies need to be performed to evaluate the functionality and efficacy of the new design concepts, and thus may require more collaboration with stakeholders at different levels of the decision process. Further evaluation with stakeholders is crucial to facilitate integration.

6.5.3 Methodological foundations for socio-technical design

Significant opportunities abound for the application of the socio-technical approach in the disciplines of visual analytics, product design, user experience design, design studies, software development, and others. Future research is needed to establish a methodological foundation for design and evaluation of industry-oriented visual analytics decision support tools. This research should be considered by human computer interaction researchers and product design professionals who are interested in introducing methods and principles into the mainstream of visual analytics. Many Human Computer Interaction (HCI) methods tend to focus on the individual whereas socio-technical methods focus on the relationships between the social context of use and the system undergoing development. We need to develop practical process to guide the use of these methods together and to integrate their results.

Results from such research may not only support the kinds of methods that were advocated in this work, but could also provide a basis for reorienting these disciplines in the direction of matching social and technical requirements in matters of design.
6.5.4 Model verification and validation

The mathematical model presented here should be verified and validated by research. The purpose of the verification and validation process is to ensure a logical level of agreement between the experimental data and model prediction, as well as the predictive accuracy of the model. Research would provide further insight to support decisions regarding placement locations for wind farms. This is one more step toward more effectively linking the model to the decision support process in Alberta.

6.5.5 Visualizing information in decision support tools

As can be seen from the results of the focus group study, visualization is a powerful medium for leveraging the visual disposition of stakeholders.

Future research is needed to understand the visual aspects of communication in VADS tools and their role in enhancing decision-making in complex domains like wind farm placement planning. This research should include the study of innovative methods, theory, and techniques for visualizing information in AB-WINDEC. It would be useful to determine and categorize the individual visual elements that a stakeholder can control, or can use to create information, or can use to communicate information when using AB-WINDEC for specific tasks. Being familiar with these principles of design and visual communication can enable a designer to create a sense of depth, variation and visual cognition for more effective and purposeful visualization of data in AB-WINDEC. It would also help avoid the mistake of designing and incorporating interface layouts that are not consistent with the visual knowledge repertoire of stakeholders.
6.5.6 Addressing the issue system security

Improving security in the implementation stage involves conducting further studies to determine security needs. Such studies should seek to understand the current security challenges are, and should also stay informed about potential security threats.

6.5.7 Design and evaluation attributes

Finally, essential questions remain to be explored on what design process should be followed in the development of interfaces that enhance the usability and usefulness of VADS tools. Specifically, there is need to define more representational attributes and metrics that are appropriate for designing VADS tools. Future research may lead to creation of more specific implementation guides to promote consistent application of standards.

6.6 Concluding Remarks

The emergence of AB-WINDEC contributes to the knowledge, development, and use of technology that can support the analysis of wind farm placement decisions in Alberta. However, the value of the tool can only be realized with further research and development. Integration of the feedback from the focus groups, especially the social and technical requirements, is the next step. The new requirements are likely to involve more detailed design techniques and implementation methods that require further research to make them compatible with each other. Importantly, the performance and usefulness of AB-WINDEC can be strongly influenced by government partnership through provision of data, research, and development.
References


Blake SP (1978) Managing for Responsive Research and Development. WH Freeman


Appendix A: Selected samples of sketch data responses from the focus groups

Description

To give more depth to the focus group data, participants were provided with blank sketch papers and print copies of the prototype’s interface. On the computer screen, participants were let to freely explore the prototype. However, for links that were not interactive, or had not been fully developed, the following message was made to appear on the screen:

‘This section of the tool you have now selected is still undergoing development. We would like your help. Please tell or show us, through writing or drawing, what you would expect to find on this page.’

Participants interacted directly with the system and these interactions provided some insights into the usability of the interface. Following this, participants were then encouraged to write notes, draw alternative sketches, or make suggestions or ideas, they may have of each interface, on the sheets provided to them.

The primary aim of this technique was to gain a deeper understanding of the stakeholder requirements beyond the data already provided by the focus group discussions and surveys. Selected samples from the anonymized data submitted by participants is posted below.
This section of the tool you have now selected is still undergoing development. We would like your help. Please tell us or show us, through writing or drawing, what you would expect to find on this page.
Welcome to Alberta Wind Decision Tool

AB-WINDEC

Sign in as a

Developer
Lender
Consultant
Researcher
Regulator
Conservation analyst
Climate change stakeholder
Member of the public

Enter

should be able to create a login so that your data, weightings, models, criteria, designs, etc. can be saved/resumed/retrieved at a later date.
Welcome to Alberta Wind Decision Tool

AB-WINDEC

Sign in as a

- Developer
- Landowner
- Consultant
- Researcher
- Regulator
- Conservation analyst
- Climate change stakeholder
- Member of the public

It's ok to sign in as different categories to streamline screens/tasks that are available.

If tool ever becomes process to do formal design and then later formal project application/submission, then:

- Submissions get assigned unique number.
- In order for users to view different levels of submitted paperwork, they should be a verified user. Then according to whatever level of viewability, they may have access to certain documents.
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<td><strong>Location</strong></td>
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<td>Scenic views</td>
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<td>Heritage values</td>
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<tr>
<td>Distance to roads</td>
</tr>
<tr>
<td>Please select one</td>
</tr>
<tr>
<td>Distance to wetlands</td>
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<td>Please select one</td>
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<tr>
<td>Distance to dwellings</td>
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<tr>
<td>10 metres per sec</td>
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<td>14 metres per sec</td>
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<tr>
<td>Communication towers</td>
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<tr>
<td>Parks</td>
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<tr>
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<tr>
<td>Private Lands</td>
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<tr>
<td>Aboriginal Métis Lands</td>
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<tr>
<td>Distance to receptors</td>
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<td>Please select one</td>
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<tr>
<td>Migrating and resident bats</td>
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<tr>
<td>None</td>
</tr>
<tr>
<td>Railway lines</td>
</tr>
<tr>
<td>None</td>
</tr>
<tr>
<td>Birds</td>
</tr>
<tr>
<td>Migrating song birds</td>
</tr>
<tr>
<td>Resident prairie grouse</td>
</tr>
<tr>
<td>Breeding grassland birds</td>
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<tr>
<td>None</td>
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</table>

<table>
<thead>
<tr>
<th><strong>AB-Windsec decision bar</strong></th>
</tr>
</thead>
</table>

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_I use about 86 constraints for wind farm design that are outside the range of what is done here._

---

_http://jbo3g1.$axshre.com/?p=location_assessment&c=1_
Bird nest area 2

- Not just nest - colonial birds
- Needs "only what has been entered"
- Description/meta data page
- What does scenic views mean?
- Heritage values?
- Are these official terms? Needs more info for people to use.

http://bq3g1.axshare.com/#=data_viewer&c=1
What is standard data files?
- shape files?
- csv limited?
Alberta Wind Farm Site Evaluation

Select Location

Project Name

Sign-off of proponent siteing proposal (Rating: 1-poor; 10. Excellent)

<table>
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<tr>
<th>Site choice</th>
<th>Noise Impact</th>
<th>Habitat Impact</th>
<th>Impact on Scenic views</th>
<th>Regulatory Compliance</th>
<th>Decommissioning plans</th>
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<td>✗</td>
<td>✗</td>
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<td>✗</td>
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<td>✗</td>
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<tr>
<td>#4</td>
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<tr>
<td>#5</td>
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<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

Regulatory Agency

[AJC]

[AESRD]

[Parks & Wildlife]

Feedback and Recommendations

Submit

This is difficult for large scale wind farms for 300 turbines