BAYESIAN INTEGRATION FOR MARINE SPATIAL PLANNING AND RENEWABLE ENERGY SITING

Kevin Halsey, Parametrix
700 NE Multnomah, Suite 1000, Portland, OR 97232-4110
Phone: (503) 416-6166 FAX: (503) 233-4825 E-mail: Khalsey@parametrix.com

Chris Goldfinger, Oregon State University
Ocean Administration Building 104, Corvallis OR 9733-5503
Phone: (541) 737-5214 FAX: (541) 737-2064 E-mail: gold@coas.oregonstate.edu
Award Number: *M10PC00089*
http://www.activetectonics.coas.oregonstate.edu/bass.htm

LONG-TERM GOALS

The primary goal of the National Oceanographic Partnership Program (NOPP) study, *BAYESIAN INTEGRATION FOR MARINE SPATIAL PLANNING AND RENEWABLE ENERGY SITING* is to develop a multi-criteria decision support tool that improves the quality of information upon which marine spatial planning decisions are made. The project team's goal is to develop a decision support tool that integrates scientific, economic and physical information associated with ocean conditions and activities with uncertainty values and critical stakeholder input to better inform the decision maker in siting renewable energy project on the Pacific coast of the United States.

OBJECTIVES

The project team is integrating existing spatial siting and cumulative effects models with Bayesian Networks[1]. The result is a tool that will score the change in social, economic and ecological processes from proposed renewable energy siting, while tracking both the model and data uncertainty within the system scoring. The initial scoring of change in social, economic and ecological processes will provide the first stage of analysis within the system. The second stage of model analysis overlays stakeholder preference values onto the stage one scoring to create a composite weighted scoring.

The system will have the ability to track sensitivities within the weighted outputs so that it is possible to determine which stakeholder values are important to the decision making process and which are not (regardless of whether there is strong stakeholder disagreement over the issue). The following objectives have been developed by the team during the first year and will be incorporated into the Bass tool during the second year of development:

- Understanding the inter-relationship between ocean conditions and the activities they support,
- Understanding the inter-relationship between the respective activities supported by the ocean resources,

[1] A Bayesian Network assembles data, measures of uncertainty, and conditional probabilities to model various aspects of the natural or human environment.

- Understanding the cumulative effects from the ongoing and proposed uses of the ocean to support these activities,
- Understanding the level of uncertainty with regard to the our understanding of the inter-relationships and cumulative effects associated with ocean conditions and ocean activities,
- Understanding the level of uncertainty associated with the data available to help identify ocean conditions and uses,
- Understanding the values of the various stakeholders to the decision making process.
- Combining the inter-relationships, stakeholder input and uncertainty values into a geographical interface system.

APPROACH AND WORK PLAN

1. Proposed Scientific and Technical Approach

The scientific aspect of this project focuses primarily on renewable energy siting decision support by providing a comprehensive knowledge of existing scientific information of the outer continental shelf ocean resources on the Pacific coast of the United States as a foundation for empirically supporting decision criteria with the best available data. The team is building on previous respective work in these areas to create a more robust and meaningful decision support tool, which for preliminary purposes has been named Bayesian Analysis Spatial Siting tool (BASS).

The project team is focused on integrating three existing technologies/tools. First, Parametrix and Aquatera (an Orkney based firm that specializes in supporting ocean renewable energy development) were hired by the Oregon Wave Energy Trust (OWET), to create a cumulative effects/renewable ocean energy siting tool. This tool includes a variety of conceptual models that define the relationship between ocean conditions and the ecological processes and human uses that rely on those conditions. The OWET tool further defines the relationship between siting of renewable energy devices and ecological processes and human uses.[2] The OWET tool uses these relationships to evaluate the potential social, economic or ecological effects of renewable energy device siting. Scientists from Oregon State University (OSU), with a background in Bayesian Modeling techniques are expressing the OWET tool conceptual models as Bayesian Networks, which introduce the ability to track the data and model uncertainty within the effects scoring provided by the OWET tool. The ocean condition features within the concept models become the nodes of the Bayesian Networks.

The second point of integration is linking the stage one outputs to a tool designed to work with stakeholder data called Accord. Accord was developed by project partner Robust Decisions. Accord focuses on integrating subjective, value based data inputs into decision-making.

2. Key Individuals

This project represents a partnership between four primary firms that each brings separate skills to the three project components that are being integrated through this project:

[2] Initial focus is on wave energy siting, but the system can be expanded to assess the effects of off-shore wind or tidal energy as well.

Parametrix

Kevin Halsey – Kevin is a co-Principle Investigator for the project. Kevin is responsible for guiding the integration of the cumulative effect concept models into the Bayesian Networks. Kevin is also leading the team that is designing the overall system structure and functionality.

Ann Radil – Ann is scientist in the Ecosystem Services Group within Parametrix. Ann was involved in the initial development of the concept models for OWET and is helping to structure their integration into the BASS tool. Ann is also a part of the BASS tool design team.

Oregon State University

Chris Goldfinger – Chris is a co-Principle Investigator for the project. Chris is leading the Bayesian Network development portion of the project. Chris is also an important part of the team that is developing the overall design for BASS.

Meleah Ashford – Meleah works with the Northwest National Marine Renewable Energy Center (NNMREC). NNMREC is providing the project with some valuable real time testing opportunities. Meleah is responsible for coordinating those and has been part of the tool design team.

Chris Romsos – Chris works in the Oceanographic Department at OSU and is responsible for converting the existing concept models into Bayes nets.

Robust Decisions

Dave Ullman– Dave is the principle developer of Accord. A Bayesian based tool designed to integrate subjective and value based data into decision making. Dave is responsible for designing the integration of the value based data inputs into the decision support tool and is an important member of the overall tool design team.

Aquatera

Gareth Davies – Gareth is the owner and principle scientist at Aquatera. Gareth worked closely with Parametrix in the development of the OWET cumulative effects tool. The OWET tool is based on a previous decision support tool developed by Aquatera called RADDMapp that has been used extensively in the U.K.

3. Year 2 Work Plan

The work plan for year 2 focuses on the following three primary areas:

a. Programming

As the project team moves into year two, the overall design of the BASS tool is being finalized and the programming has begun to capture the inter-relationships noted prior in this report. Programming will

entail setting up the interface for the system and creating the necessary connections between the component parts.

b. Testing/Refining

In January the project team will use the current proto-type of the BASS tool to support the NNMREC testing facility siting process. The first part of NNMREC's siting process (narrowing the selection to four potential sites), was done with the aid of OWET's cumulative effects tool. The second part of the decision will use the integrated components of the BASS tool to refine the understanding of the issues, particularly those associated with stakeholder values. The testing will entail running the tool with the NNMREC test center stakeholder group, which has been created to provide a representative stakeholder input into the siting process.

c. Reporting/Documenting

The Reporting/Documenting task will run concurrent with the other two tasks and will include, 1) developing a user's manual and reference materials for the BASS tool; and, 2) a project report that outlines the process and decisions that were made throughout the course of the project.

WORK COMPLETED

The project team has focused on various aspects of system integration and design during the first year. The various project partners have worked together to identify how the discreet system components relate, how they can be integrated together, and the overall functionality of the system that will be provided.

The team used this information to develop a working mock-up of BASS that provides all the functionality of the ultimate system. The mock-up has provided invaluable support for refining the inter-relationships to be included in the later prototype system. Although the mock-up is fully functional, it lacks the necessary programming to run in a smooth interconnected fashion at this time.

RESULTS

The primary question the project team faced going into the project was how the OWET tool could be converted into a Bayesian Network and combined with Accord to allow stakeholder values to be reflected in the scientific scoring. During the course of the first year, the team addressed this question by defining the relationships between the types of information that support a decision-making process. The team identified several important concepts that have been adopted as the basis for system design. First, although it is important to include both scientific analysis and stakeholder values as part of a decision-making process, they must be in sequential steps for better utilization. Second, to provide the best information to support a decision making process, it is best if the respective outputs from the scientific analysis are not aggregated. Doing so will obscure important information, while providing little actual benefit since the aggregation will tend to just be an averaging of the respective outputs. Third, unlike the scientific analysis, the stakeholder weighted out-put is much more useful to decision making when expressed as an aggregation.

IMPACT AND APPLICATIONS

National Security (Delete this section if there are none)

The project is developing a decision support tool to improve the effectiveness of decision-making associated with multiple uses of the ocean along the Pacific coast of the United States. An anticipated outcome of the tool is the most preferred siting of renewable energy devices in an ocean environment, which will have the capability of handling information related to national security as necessary and appropriate. To the extent that the model may consider issues related to national security in its review of renewable energy sites, this project may play a small and incremental role national security.

Economic Development (Delete this section if there are none)

The renewable energy industry has significant potential for providing new jobs in a variety of sectors, including among others design, manufacturing, deployment and maintenance. To the extent the project is able to increase the likelihood of successful deployment of renewable energy devices it is aiding the economic development of coastal communities and the manufacturing facilities within the near vicinity. However, just as importantly, the tool is designed to aid new economic development without significantly impacting existing economic activity through more efficient renewable energy siting. The tool is designed to help work through the identification and analysis of renewable energy sites that are the most environmentally sound and least likely to impair existing ocean activities

Quality of Life (Delete this section if there are none)

The BASS tool is expected to improve coastal resource management, and hence ecosystem health and ecosystem service benefits through the process of better and more efficient renewable energy siting. Sound resource management requires the best information and most comprehensive approach upon which to base decisions. Coastal resource managers require a clear understanding of potential environmental impacts, oceanographic conditions and stakeholder values to make the best possible renewable energy siting decisions that are compatible with and enhance local and regional quality of life issues. Examples of quality of life issues envisioned with the development of the BASS tool include better understanding of the inter-relationships between multiple uses of ocean resources and activities and community values to ensure the development of environmentally sustainable renewable energy sources to support the energy needs of coastal communities.

Science Education and Communication (Delete this section if there are none)

An important aspect of decision support tools is that they capture the current best understanding of how ecological systems work, including all the interrelationships between ocean conditions that allow those processes to occur. Every model within the system seeks to pull together the best science available on the topic. By doing so in a measurable way it allows us to start testing our best science in a more systematic manner. Further, by incorporating Bayesian uncertainty analysis, the system provides guides to where our understanding is the weakest and most in need of testing. Ultimately this means we have a much better understanding of what we “know” about our ecosystem and how we

relate to it. This improved understanding is an important aspect in science education and communicating science issues in a policy context.

With regard to communicating science, we currently do a poor job communicating the complexities of systems in a manner that makes it possible for decision-makers to incorporate systems thinking into decision-making processes. The result is that we often default to reductionist thinking for problem solving and decision-making. The end result is a proliferation of unintended consequences. The BASS tool is built around systems and relating to other interrelated systems. As such we anticipate it will improve scientific communication in a critical fashion.

TRANSITIONS

National Security (Delete this section if there are none)

Although there are no actual outcomes at present, BASS is being used to help NNMREC consider siting options along the Oregon Coast for a grid connected wave energy test center. One of the sites is the Oregon National Guards Camp Rilea. Although, still early in the process, Camp Rilea is in consideration because the Camp is in need of a more stable power source in case of a natural disaster or military emergency. The Camp is an emergency center for that part of the state and provides many important functions that require a secure power source to ensure national security readiness.

Economic Development (Delete this section if there are none)

The BASS tool is already being used to aid wave energy siting in Oregon through use siting the NNMREC grid connected testing facility. This is expected to lead to increased efficiency due to improved consideration of social, economic and ecological issues, as well as improved stakeholder outreach during the early siting process.

Quality of Life (Delete this section if there are none)

The foundational databases making up the BASS tool are presently being used by the wave energy industry to support their input into Oregon's ongoing Territorial Sea Plan (TSP) process. Accordingly, BASS is envisioned to be used by multiple local, state and federal agencies and industry to more efficiently determine appropriate renewable energy sites that better reflect more consistent and comprehensive decision making.

In addition, as was noted earlier, the NNMREC facility operated by Oregon State University is using the BASS tool to help site their grid connected test facility and to additionally validate the robustness of the Bass tool in determining four potential sites off the coast of Oregon.

RELATED PROJECTS

The development of the BASS tool is building off the earlier work funded by the Oregon Wave Energy Trust (OWET). The OWET project provided important foundation material that was used as a starting point for the project. Additional information on OWET and the project may be accessed at

http://www.oregonwave.org/. The project has also utilized some of the material from the BOEM Conflict Resolution Study as it has become available.

REFERENCES (*DELETE THIS SECTION IF THERE ARE NONE)*

Alcamo, Joseph, and Millennium Ecosystem Assessment (Program). 2003. *Ecosystems and human well-being : a framework for assessment*. Washington DC: Island Press.

Daily, Gretchen. 1997. *Nature's services : societal dependence on natural ecosystems*. Washington DC: Island Press.

Hassan, Rashid, and Millennium Ecosystem Assessment (Program). 2005. *Ecosystems and human well-being : current state and trends : findings of the Condition and Trends Working Group of the Millennium Ecosystem Assessment*. Washington DC: Island Press.

Paul Longley, Michael Goodchild, David Maguire, and David Rhind. 2001. *Geographic Information Systems and Science*. Chichester: Wiley.