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Solar Wind and Energy Resource Assessment (SWERA): A Usability Case Study

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Abstract: The Solar Wind and Energy Resource Assessment (SWERA) project focused on providing renewable energy planning resources to the public. Examples include wind, solar, and hydro assessments. A major component of the SWERA website is the archive search. This provides for a discovery DSS upon which users can find and access renewable energy data and supporting models. The RREX component of SWERA provides a visualization DSS as an addition to the website archive. RREX provides the discovery through a couple different avenues. RREX maps the renewable energy data that it provides along with a graphing application of the same data. RREX also provides a web service approach to allow for the distribution of the same data sets in multiple forms. The objective of this paper is to evaluate user satisfaction with the system as well as highlight factors affecting user satisfaction and experience. In the paper we provide a discussion of various design decisions used in the construction of the system followed by description of research methodology, and a discussion of key findings. Overall, analysis of results indicates general acceptance of the functionality provided and highlights venues for further improvements of the interface.

Keywords: DSS; User Acceptance; SWERA

1. INTRODUCTION

With the increasing demands for energy coupled with the increasing environmental concerns (as signified by the recent United Nations Summit on Climate change), the significance of renewable energy (RE) will continue to grow as a viable and sustainable source of energy. The harnessing of solar, wind, and hydrological energy can produce energy to manufacturing plants, homes, businesses, and a multitude of other applications. A critical component of planning for RE development is determining the optimal location for RE plant, i.e., which locations would be most viable for a particular RE plant. This is accomplished through collecting and analyzing data assessing the RE potential for a particular location, also referred to as RE assessments. Accordingly, the ability to access and analyze RE assessments at a various levels of granularity is a major factor to making informed decisions. However, such data is not necessarily available to planners and decision makers at the level of detail and quality to meet their planning needs. Moreover, even in cases where the data is available, it is not necessarily in a readily usable format. Decision Support Systems (DSS) can go a long ways towards facilitating access to relevant RE assessments and support data visualization and analysis tools.

In this paper we describe the Solar Wind and Energy Resource Assessment (SWERA) DSS which focuses on providing renewable energy planning resources to RE planners and decision makers. Examples include wind, solar, and hydro assessments. The objective of this paper is to evaluate user satisfaction with the system as well as highlight factors affecting user satisfaction and experience.

The remainder of the paper is organized as follows; the following section provides a background about DSS usability followed by a description of the SWERA-DSS and its various components. Next, we describe the research methodology followed by a discussion

of the results. Finally, we conclude with a summary highlighting lessons learned and emphasizing key findings with implication for future system development.

2. DSS USABILITY

Renewable energy has become of growing interest particularly in the environmental community. However planning for RE projects aimed at harnessing the power of renewable energy resources can be costly in terms of money, time, and other resources. The minimization of these is considered a high priority. Decision Support Systems (DSS) have been shown to help with decision making (Vicki 1999; Vicki 2005; Kamran and Mohammad, 2007). Terry and Spence (2005) also studies the types of decision making that makes for a more successful project. It was shown that through the difference in decision making processes that time to completion of the project, as well as the accuracy were found to be greatly enhanced when using a tool to help in this process. Another key aspect to this research is the acceptance of the DSS. With technology resistance is something that needs to be considered, Tim et al. (2007) examine user resistance towards an Enterprise System. The same factors examined can also apply towards other implementations of technology including DSS. Other research has also been done into the acceptance of DSS in terms of the models they present (Hsi-Peng Lu, Hwei-Ju Yu et al. 2001). When trying to affect the perceived usefulness, affecting the perception that the DSS is easy to use has a direct affect. Diez and McIntosh, (2009) considers the factors that impact the use and usefulness of Information Systems while Turner and Kitchenham (2010) conduct a meta-literature review of the technology acceptance literature and the relationship to actual use. The use of DSS within the confines of the renewable energy field has also been discussed in literature. One such demonstration of a DSS and its implementation is shown by Meulen (van der Meulen, 1992). Other such implementations instances of DSS furthering RE use can be found in (Cherni and Dyrner, 2009; Georgopoulou, 1998).

3. SWERA

Renewable Energy and “Going Green” have become key concerns in today’s economy. Implementation of technology is needed in order to further incorporate this type of energy into a form that society can use. This type of energy however is not viable in all locations around the world. In fact, some locations may be limited to only some forms of renewable energy usage, while some may be further limited to none. The decision to implement the use of such technology in regions around the world can be a costly endeavour in terms of the effort to design, construct, and implement a working renewable energy resource energy plant of any kind. Accordingly, access to reliable region-specific RE assessment is vital to understand whether candidate locations are viable or cost effective to implement such a plant. The Solar Wind and Energy Resource Assessment (SWERA) project came into being to try to help fill this need. SWERA was focused on 13 developing countries as a starting point. With the information that would be provided through SWERA, it is the hope that future solar and wind projects would be aided in their decisions to plan and execute renewable energy projects within these countries.

Another main focus of SWERA was to act as a sharing center for countries and organizations. Through the project government agencies would be allowed to share information with interested parties. Industry personnel, investors, and other researchers would be able to find this information accessible and incorporate the shared information within their research and decision making. SWERA makes data for developing countries further accessible and the use of such energy resources appealing to private as well as public investors. In effect, renewable energy resource potential is helped to be fully realized within the different locations. Through SWERA, consistent, reliable and verifiable data is shared with investors, lawmakers, government agencies, and any other concerned parties. Not only is the data shared through SWERA, but also different geospatial toolkits are also available upon which to access and use the data. High resolution data is also available upon which to analyze, use, and interpret to further the interest and potential use of renewable

energy resources. SWERA also provides an interface upon which to easily find and access information in such a way as to make the information more easily accessible to the public.

4. SWERA DSS COMPONENTS

The SWERA DSS is made up of two major components. The first is an archive tool that allows for the creation, storage, searching, and downloading of renewable energy data products, tools, and information. The other component is the Renewable Resource EXplorer (RREX). This serves as an analysis tool for some of the data sets that are housed within the SWERA Archive. Through RREX some data sets are visually viewable with additional analysis done by point locations selected by the user. In order to further incorporate the goals of the project within the SWERA system, an archive system was created. The overall goal of the archive system is to allow project sponsors, government agencies, and other users of the system the ability to share their information through the SWERA system. The system allows for the upload of information from any web browser. Data has a couple major components to it that need to be completed in order for the information to be accessible through the web. Data must have a contributing organization, a data provider, along with further information about the data set itself and metadata about the information. This data is necessary for data discovery and for the users to understand the data enough to put the information to use in valid ways. The information required conforms to the information specified through the OGC specification for spatial data metadata records. The archive systems also allows for the searching of the database amongst different categories such as energy type, location, and product type. Once a record is found, further information, links to the products, and downloads can all then be accessed. When information is requested for download, the user is asked to give information about who they are and what they are using the information for. In this way, the SWERA project team can gain a better understanding of the system users.

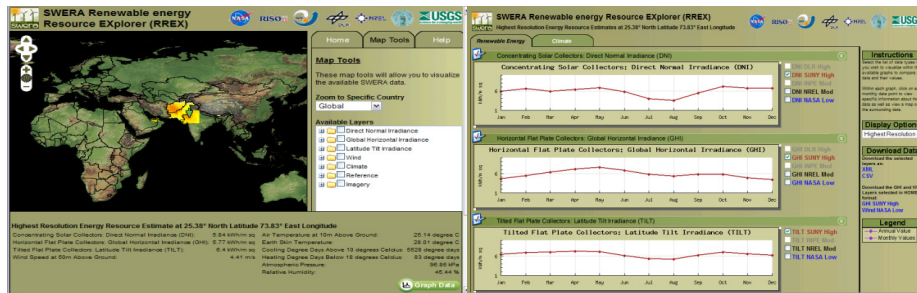


Figure 1 RREX Screenshot

The other component to the SWERA DSS is the Renewable Resource EXplorer (RREX) (See figure 1). RREX is built upon the OpenLayers platform for mapping data layers. RREX also uses KaMap's mapping and tile generation components to tile the images presented through the RREX mapping tool. In this way images are loaded faster because they are cached already and provide the user with a faster visual display. RREX also provides for visual display of other layers through the "Map Tool" menu and additional pop-ups when clicking on the layers that link back up to the SWERA Archive search. Additional point analysis can also be done for locations on the map with a mouse click to select the location. From the brief analysis of the location selected, the user can then graphically see representations of the data sets that are available for that point location through the graphing component of RREX. Bar graphs are dynamically built based upon the information from the map click. Each plot point on a graph that is not made up of annual values is also a dynamic link to a mapping feature on the bottom of the page. Here additional analysis can be done the a zoomed in location of the point that was originally selected along with a time series look at that location over the course of 12 months. All of the information that is being presented on the graphing page is also downloadable through links on the page in a CSV, XML, and with applicable data sets a HOMER format.

5 RESEARCH METHODOLOGY

5.1 Research Model and Hypotheses

The research model for the study is shown in Figure 2 (Doll and Torkzadeh 1988). This model was chosen over the TAM model (Davis, 1989) for the constructs employed and the emphasis on end-user satisfaction as opposed to intention to use which is the focus of TAM. The 5 major constructs give a well rounded depiction the End-User Computing Satisfaction (EUCS) which is the focus of this study.

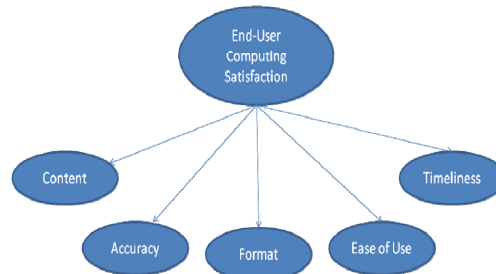


Figure 2. Adopted from (Doll and Torkzadeh 1988).

Using the research model as shown above, we hypothesize the following:

- H1: The degree to which the system satisfies the content needs of the end user has a positive impact on his/her satisfaction
- H2: The degree to which the system satisfies the accuracy needs of the end user has a positive impact on his/her satisfaction
- H3: The degree to which the system satisfies the formatting needs of the end user has a positive impact on his/her satisfaction
- H4: The degree to which the system satisfies the timeliness needs of the end-user has a positive impact on his/her satisfaction
- H5: The degree to which the system perceived as easy to use by the end-user has a positive impact on his/her satisfaction

5.2 Setting, Context and Subjects

The survey was conducted through Checkbox, an online survey system. The subjects of the test consisted of registered users of the system and anonymous (unregistered) users. Registered users had downloaded a data product through the archive tool and registered their information. Unregistered users were those that accessed the survey through a link on the home page of SWERA.

5.3 Survey Instrument

The survey instrument is based on constructs that were previously validated in research (Doll and Torkzadeh 1988). The constructs are Content, Accuracy, Format, Ease of Use, Timeliness, with an overall construct of End-User Computing Satisfaction. Other questions were added to the constructs from other research studies (Dimbleby et al. 2005; Shneiderman and Plaisant 2005). Along with the questions that were used for the study, additional questions were included to capture user's affiliation, system usage, and the importance of different data sets that were included within the system.

5.4 Data Collection

Registered users were sent out emails to addresses provided during the download process. This email contained a direct link to the survey along with an informed consent statement. Unregistered users accessed the survey through a link on the homepage of SWERA, where an informed consent was also visible at the beginning of the survey. In both cases, the anonymity of the subjects was maintained during the survey in the way that their email, if provided, was stripped from the results was not reported from the survey for the data set used in the survey. The data collected through Checkbox was transferred to a spreadsheet, excluding the email, and further analysis was done.

5.5 Data Analysis

Partial Least Squares (PLS) is the analysis technique used in this study. The utility of PLS is detailed elsewhere (Falk and Miller, 1992), and a number of recent technology studies have used PLS (e.g., Al-Gahtani (2001), Compeau (1995a), Venkatesh (2003)). To evaluate the measurement model, PLS estimates the internal consistency for each block of indicators, then evaluates the degree to which a variable measures what it was intended to measure (Cronbach, 1951; Straub, Boudreau and Gefen, 2004). This evaluation is known as construct validity and is comprised of convergent and discriminate validity. Following previous work (Gefen and Straub, 2005), convergent validity of the variables is evaluated by examining the t-values of the outer model loadings. Discriminate validity is evaluated by assessing item loadings to variable correlations and by examining the ratio of the square root of the AVE of each variable to the correlations of this construct to all other variables (Chin, 1998a; Gefen and Straub, 2005). With respect to the structural model, path coefficients are understood as regression coefficients with the t-statistic calculated using a bootstrapping method. Bootstrapping is a nonparametric technique used to estimate the precision of PLS estimates (Chin, 1998a). 200 samples are considered satisfactory (Chin, 1998a). To determine how well the model fits the hypothesized relationship, PLS calculates an R^2 for each dependent construct in the model. Like a regression analysis, R^2 represents the proportion of variance in the endogenous constructs which can be explained by the antecedent constructs (Chin, 1998a).

6. RESULTS AND DISCUSSION

6.1 Sample Characteristics

The survey was sent out to approximately 3000 registered users of the system. A total of 26 responded to the survey. 2 additional users responded through the website survey. The majority of the questions were assessed on a 5-point Likert scale with some of the questions being assessed on a 2 point scale.

6.2 Assessing Measurement Validity

Using PLS-Graph (Chin, 1998) we examine 5 variables initially included in the survey instrument. Items that exhibited loadings of less than the 0.7 were removed as indicated in the literature (Compeau and Higgins, 1995a; Compeau and Higgins, 1995b; Fornell and Larcker, 1981). The removed items are deemed as not contributing to the underlying construct (Hair, Black, Babin, Anderson and Tatham, 2006). The remaining items adequately represent the underlying constructs attesting to the content validity of the instrument. Table 1 summarizes the results for the items comprising the model. The results show composite reliability (CR) exceeding 0.8 as recommended (Nunnally, 1978). AVE, which can also be considered as a measure of reliability exceeds 0.5 as recommended (Fornell and Larcker, 1981). Together, CR and AVE attest to the reliability of the instrument. Verifying the convergent validity of the instrument, the t-values of the outer model loadings exceed 1.96 (Gefen and Straub, 2005), with two notable exception (format $t=1.19$ and EOU $t=1.13$) in the RREX data set. Calculating the correlation between variables' component scores and individual items reveal that intra-variable (construct) item correlations are generally high when compared to inter-variable (construct) item correlations (Table 1).

6.3 Model Testing Results and Discussion

Figure 3 depicts the combined (PS+RREX) structural model with path (regression) coefficients and the R^2 for the variables: content ($R^2 = 53.1\%$), accuracy ($R^2 = 47.6\%$), format ($R^2 = 54.9\%$), EOU ($R^2 = 49.0\%$) and timeliness ($R^2 = 57.1\%$).

Table 1. Analysis results

Dimension	Code	Question	Mean	S.D.	Item Loading	CR	AVE
Content	C					0.923	0.670
	C2	The system provides information content that meets my needs	3.5	1	0.876		
	C3	The system provides useful information	3.89	.99	0.886		
	C4	The system provides sufficient information	3.46	.96	0.812		
	C5	Use of terminology throughout the system was	3.46	1.2	0.602		
	C6	Overall, I feel the system meets my needs	3.39	.88	0.839		
	C7	Overall, I feel the terminology relates well to the work I am doing	3.5	.92	0.863		
Accuracy	A					0.939	0.885
	A1	The system provides accurate information	3.64	.87	0.933		
	A2	Overall, I feel satisfied with the accuracy of the system	3.54	.79	0.949		
Format	F					0.843	0.642
	F1	Overall, I feel the output is presented in a useful format	3.5	1	0.726		
	F2	Overall, I feel the presentation of the system is attractive	3.32	.98	0.831		
	F3	Overall, I feel everything on the system is easy to understand	3.5	1.04	0.842		
Timeliness	T					0.846	0.650
	T2	Length of delay between operations is	3.07	.98	0.795		
	T3	Overall, I feel the system keeps me informed about what it is doing	3.18	1.02	0.687		
	T4	Overall, I can get the information I need in time	3.46	.92	0.726		
Ease-of-Use						0.962	0.698
	EoU1	The system is user friendly	3.54	1.04	0.857		
	EoU2	The system is easy to use	3.71	.98	0.899		
	EoU3	The system is easy to learn	3.57	1	0.904		
	EoU4	The system is easy to get it to do what I want it to do	3.46	.96	0.803		
	EoU7	I feel learning to operate the system was	3.14	1.04	0.856		
	EoU8	I feel getting started was	3.11	1.1	0.823		
	EoU9	I feel learning advanced features was	2.82	1.09	0.819		
	EoU10	I feel the time to learn to use the system was	3.21	.99	0.825		
	EoU11	I feel discovering new features was	2.93	1.12	0.787		
	EoU13	The number of steps per task was	3.18	1.06	0.799		
	EoU14	Overall, I feel the tasks can be performed in a straight-forward manner	3.25	1	0.808		
End-User Satisfaction	OS					0.949	0.756
	OS1	Overall the system was satisfying	4	1.22	0.898		
	OS2	Overall the system was easy	3.68	1.09	0.767		
	OS3	Overall how satisfied are you with the SWERA website	4.21	1.1	0.918		
	OS4	Overall how satisfied are you with the SWERA mapping and graphing tools (RREX)	3.61	1.17	0.793		
	OS5	Overall how satisfied are you with the SWERA product search	3.82	1.17	0.895		
	OS6	Overall how satisfied were you with the SWERA system	3.93	1.25	0.930		

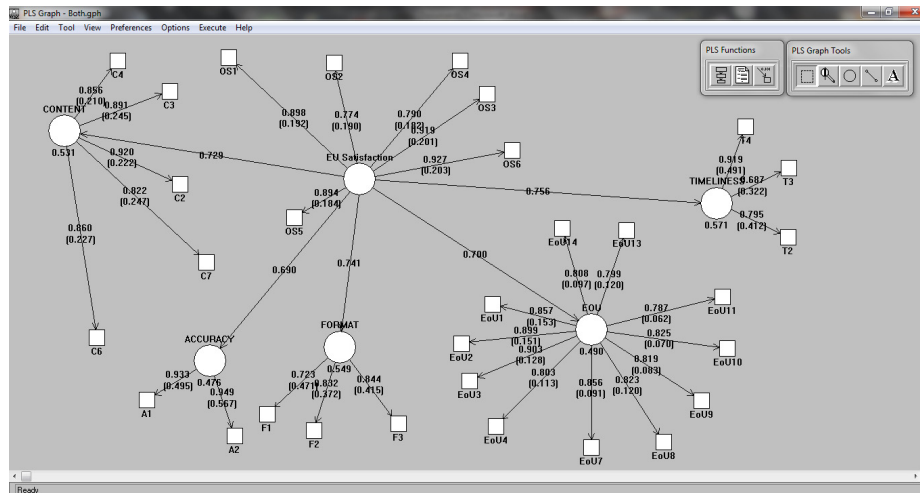


Figure 3 PS+RREX Structural Model

6.4 With PLS Graph Model

With respect to the determinants of end-user satisfaction in the combined model (PS+RREX), all constructs are significant: content ($\beta = 0.729$ $p < 0.0001$), accuracy ($\beta = 0.690$ $p < 0.0001$), format ($\beta = 0.741$ $p < 0.0001$), EOU ($\beta = 0.700$ $p < 0.0001$) and timeliness ($\beta = 0.756$ $p < 0.0001$). These findings are consistent with prior work (Doll, 1988). Examining the PS model data alone, content ($\beta = 0.640$ $p < 0.0001$) is statistically significant, along with EOU ($\beta = 0.763$ $p < 0.0001$), Timeliness ($\beta = 0.679$ $p < 0.0001$), format ($\beta = 0.542$ $p = 0.0006$) and accuracy ($\beta = 0.512$ $p = 0.0069$). The RREX data alone is notable in that content, accuracy, and timeliness are all significant at the $p < 0.0001$ level, while format ($\beta = 0.792$ $p < 0.2591$) and EOU ($\beta = 0.797$ $p < 0.2825$) are insignificant. The combined data suggests that end-user satisfaction with the system is a function of the measured variables of content, accuracy, format and timeliness. Overall, user evaluations for the five dimensions of end-user satisfaction considered in this study are positive. Moreover, the model exhibits a good fit with the data and provides a satisfactory explanatory power for end-user satisfaction with the system.

7. CONCLUSION AND FUTURE WORK

The use of the EUCS construct (Doll and Torkzadeh 1988), allows for the validation of the user satisfaction construct with the system. Through the PLS analysis, the constructs show to have significance when looking at the system as a whole. Overall, the users were satisfied with the system. As a generalization, the results further validates the significance of the content, timeliness, ease of use, accuracy, and format on user satisfaction with environmental decision support systems. The limitations of this work relatively small sample size. Additional work could be done to expand the sample size to further validate the findings. With respect to the SWERA-DSS, additional work could be done to find new ways to reduce delays within the system being as timeliness had the lowest average mean amongst the constructs.

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