

Improving the Utility of Green Building Certification Resources

Dwayne Jefferson¹ and Frederick Paige²

¹Charles Edward Via, Jr. Dept. of Civil and Environmental Engineering, Virginia Polytechnic Institute and State Univ., Blacksburg, VA. E-mail: dejeffer@vt.edu

²Society Technology Infrastructure and Learning Environments Research Team, Charles Edward Via, Jr. Dept. of Civil and Environmental Engineering, Virginia Polytechnic Institute and State Univ., Blacksburg VA. E-mail: freddyp@vt.edu

ABSTRACT

A great deal expert knowledge is required to design complex sustainable infrastructure systems such as energy-efficient, affordable multifamily housing units. A more accessible understanding of how to optimize green building systems is needed to allow more builders and designers to engage in the delivery of sustainable construction projects. EarthCraft Multifamily (ECMF), a green building certification, was designed for traditional builders to engage in the process of delivering affordable sustainable multifamily units. To date, has certified more than 45,000 energy-efficient housing units. This study aims to improve the accessibility and usability of ECMF tools and resources such as the program manual, worksheet, and technical guidelines. User experience (UX) methodologies are being leveraged to enhance ECMF resources' delivery of affordable sustainable housing. User interviews, stakeholder interviews, and heuristic evaluations provide detailed information on the usability strengths and weaknesses of ECMF. Preliminary findings show potential for EarthCraft resources to evolve in their layout, content, and delivery methods. It has also been found that ECMF tools have encouraged the selection of optimal sustainable design practices in new construction and renovation projects. While a base level of expertise will always be needed in infrastructure delivery for safety reasons, the delivery of sustainable designs can be more accessible to a larger range of stakeholders by improving user experiences of resources and tools. By making the process more approachable, non-expert stakeholders can better manage their role in the process. The procedures and findings from this study are transferable to other green infrastructure rating/certification programs, with similar resources, such as LEED and Envision.

INTRODUCTION

Green building certifications are an emerging open access method for providing sustainable engineering guidance to designers (Retzlaff, 2008). Green certifications guide builder-developers on their path to deliver sustainable infrastructure to consumers. ECMF certifies low-rise and mid-rise multifamily projects based upon standards that address sustainability concerns (Southface, 2018). Over the years, project teams have utilized EarthCraft resources to assist in delivering buildings which are more sustainable than traditional housing units. The primary resources of ECMF include, the program manual, worksheet, and technical guidelines.

When dedicating funding to the development of an affordable sustainable housing project, the design and plan for delivery are tightly constrained (McCoy et al., 2015). Studies have shown the complexity of the correlation between building technologies and user behavior (Zhao et al., 2017). The utilization of energy models and simulations are plagued by a great deal of inconsistency which introduce risks in ECMF projects (Clevenger & Haymaker, 2006). With a better understanding of who is using ECMF resources, and how, unexpected consequences may

be mitigated due to user error during the delivery of affordable housing units (McCoy et al., 2015). EarthCraft has been shown to be successful, but improvements can still be made to increase utilization while also reducing the risk for in a risk adverse industry (Zhao et al., 2016).

User experience (UX) is best described as all aspects of a person's experience with a system (Lallemand et al., 2015). UX is often considered human-centered design that aims to make systems useful and usable in interactive systems advancement. While the concept of usability mainly focuses on an objective approach of an interaction, UX explores emotional, subjective, and temporal aspects characterizing the experience between human and technology (Lallemand et al., 2015). The field of Civil Engineering could benefit from implementing UX methodologies into its projects.

In Civil Engineering, we have mostly focused on assessing the usability of our projects' outputs and not the way we develop those outputs (Sengers, 2018). Readability, legibility, order of information, and delivery platforms such as documents and interfaces are usability factors that can affect the resources utilized in engineering. Civil Engineers can benefit from utilizing usability studies to iterate our decision-making processes in social and technological dimensions as they become more complex over time (Norman, 2013). By tying UX and Civil Engineering together, we ensure that tools and resources are being utilized effectively and efficiently. This study aims to investigate ways of increasing the accessibility and utility of ECMF tools and resources.

METHODS

An exploratory case study was determined to be ideal to achieve the broad goal of investigating ways to increase the accessibility and utility of ECMF tools and resources. By conducting an explorative case study, we can analyze project specifications, user interviews, stakeholder interviews, and heuristic evaluations. The strengths and weaknesses of ECMF can be identified after a great deal of knowledge is unlocked about the green building certification program (Retzlaff, 2008). The conceptual understanding that will be focused on in this case study will significantly enhance the broad goal of this research study.

Conducting an exploratory case study

The case study methodology is to be ideal to holistically explore the contemporary experience of utilizing ECMF resources (Yin, 2018). This exploratory case study consists of two phases: 1) qualitative usability analysis of the influence ECMF resources have on technology utilization and 2) qualitative analysis of builder-developer interview transcripts describing experiences using ECMF resources.

The usability analysis takes a deductive approach that leverages design theories by prioritizing accessible design standards. While the preliminary portion of this project is exploratory, there is great potential to transition from a general idea to specific theories which exist in separate domains (Fellows & Liu, 2015).

Phase 1: Qualitative usability analysis of the influence of EarthCraft Multifamily resources

Usability analysis framework

The usability analysis framework links construction management theories and universal design concepts to serve as a basis for developing the framework needed for experimental user

testing (Blythe et al., 2007). These concepts include project scale, scope, stakeholders, project delivery methods, interface design, and appropriate communication strategies (Retzlaff, 2008).

Heuristic evaluation methodology

Heuristic evaluation is a method for having individual evaluators perform an analysis that visualizes the state of a product in terms of usability and accessibility (Nielsen, 1994). Evaluators, usually with backgrounds as specialists and experts, use industry-accepted guidelines for usability and prior experiences to complete the evaluations. For this research study, three UX experts serve as the evaluators. The three evaluators were selected due to their backgrounds and expertise with UX. One evaluator is a UX researcher and designer, another is an associate professor with previous ECMF experience and knowledge regarding human factors in construction, and the last evaluator has research experience with UX and ECMF. To determine usability, heuristic evaluations will be performed on ECMF tools and resources focused on the heuristics listed below (Nielsen, 1994):

- Visibility of system status
- Match between resource and the real world
- User control and freedom
- Consistency and standards
- Error prevention
- Recognition rather than recall
- Flexibility and efficiency of use
- Aesthetic and minimalist design
- Help users recognize, diagnose, and recover from errors
- Help and documentation

The tools and resources of ECMF that will be analyzed include, but are not limited to, the program manual, worksheet, and technical guidelines. The major aspects of each resource that will be observed during the heuristic evaluations are navigability, page design, page layout, and content quality.

Heuristic evaluations are valuable when resources and time are limited (Kantner & Rosenbaum, 1997). Each evaluator spends approximately two hours during their evaluation sessions for this research project. Two hours allows the evaluator to thoroughly analyze ECMF tools and resources for the previously mentioned usability principles and elements. Each evaluator evaluates each tool and resource at least twice. The first time to get a feel for the flow of the tools and resources, and the second time to focus on key elements that capture attention. Violations to the heuristics are recorded during the evaluation process via tabular tally system. In addition to counting the violations, the evaluators also rate the severity of the violations. Severity is defined as expected impact on the user's experience.

After each evaluation session, the evaluator discusses heuristic violations and usability problems, as well as beneficial features of each tool or resource with the research team (Kantner & Rosenbaum, 1997). Common ground between the separate evaluator findings will be found and organized through group meetings with the three evaluators. The heuristic violations, usability problems, and beneficial features will be compiled into a rating scale where each is individually scored from 0% to 100% based on how evaluators view each's effectiveness in the utilization of the tools and resources. 0% is the lowest percentage a violation or feature receives due to a lack of effectiveness in the tool or resources and 100% is the highest due to a high level

of effectiveness. The findings from the heuristic evaluations will also be used to make changes to the tools and resources that will be utilized in the A/B testing phase.

Piloting Stage

There is a piloting stage before A/B testing sessions begins to determine the best experimental set up for study participants. The hardware and software are checked for performance to verify their ability to capture participants varying experiences. After analyzing the two versions of the tools and resources, the participants provide feedback to the research team regarding their experiences as participants in this A/B testing.

A/B testing methodology

A/B testing is a method of isolating and testing factors that impact the performance of green building certification resources (Dixon et al., 2011). A/B testing allows for two different versions of ECMF tools and resources to be tested among groups of builder-developers and the usability of each version is compared. Version A of the tools and resources is the original version of ECMF tools and resources while Version B includes multiple improvements that are implemented to the formatting and design of the original version. Version B is created from the findings from the heuristic evaluations. A/B testing is conducted on the ECMF program manual, worksheet, and technical guidelines.

Builder-developers from previous ECMF projects used in studies (Zhao et al., 2017; Zhao et al., 2016) are recruited to participate in the study. A sample size of 10 builder-developers with previous ECMF experience was determined to be ideal for this research study based on each of the builder-developers familiarity with EarthCraft. The builder-developers are asked to view both versions of ECMF tools and resources as if they were utilizing them on an actual company project. During each session of A/B testing, participants are also asked to fill out various sections of the ECMF worksheet while referencing back to the technical guidelines and program manual for assistance.

A script is followed during each session of A/B testing to ensure that each builder-developer is being presented with the same tasks and questions. This allows for each builder-developer to effectively analyze the two versions of ECMF without being influenced by my words or descriptions. The participants provide feedback regarding their experiences in a feedback section after analyzing the two versions of the tools and resources.

The A/B testing section of this study is considered to have a within-subject design, so a counterbalance is needed to offset a potential ordering effect. The first participant of the study first, analyzes the original version of ECMF tools and resources and second, analyzes the improved version of the tools and resources. The second participant of the study first, analyzes the improved version of the tools and resources and second, analyzes the original version of the tools and resources. This process of counterbalancing is repeated throughout the study for every two participants. If any of the participants' data is deemed insufficient to the collection of data or the results prove to be an outlier, the participant's data is removed from the collection.

A/B testing sessions are held in a secluded media design studio on Virginia Tech's campus. This location is ideal because it provides the builder-developers with a work environment similar to the environment they utilize on their projects. The locations also allow for adequate use of the equipment that contribute to the success of the A/B testing sessions.

The equipment needed to complete an A/B testing session are a Blue Yeti USB Microphone, Camtasia 2019 software, and any computer that can display EarthCraft Multifamily tools and

resources. The participants speak directly into the microphone as they progress through the versions of ECMF tools and resources exemplifying a think-aloud method. The Camtasia 2019 software is utilized to document participants' voices and screens while they progress through the two versions of tools and resources.

Usability analysis of tools and resources

Following the completion of heuristic evaluations and A/B testing, a usability analysis of tools and resources will be organized to present the qualitative aspects of the data. The data from the heuristic evaluations and A/B testing will be analyzed in which specific features such as readability, legibility, hierarchy, and navigability are highlighted. The impacts and analyses of the resources will be recorded in a three-column table in Microsoft Excel as shown in Figure 1.

USABILITY ANALYSIS OF TOOLS		
Tools	Function	Analysis of
Program Manual	Provides steps to successful project delivery; Customizable program to meet needs of stakeholders	Bolded headings; Direct transitions to desired sections
Worksheet	Must be completed to show that a project qualifies for certification	Sections highlighted with colored backgrounds; Separate sheets highlighted by several colors
Technical Guidelines	Used in conjunction with Worksheet and explains for each line item	Bolded headings; Direct transitions to desired sections

Figure 1. Usability analysis of ECMF tools and resources

Phase 2: Qualitative analysis of builder-developers interview transcripts

Builder-Developer interviews

Builder-developers will be asked with open ended questions to provide deeper understanding of how and why builder-developers access and utilize ECMF tools and resources. Open questions allow for the respondents to reply in a narrative manner, in which participant's experiences are highlighted (Fellows & Liu, 2015). Audio from the interviews are recorded and transcribed for analysis.

Interviewee selection

A total of 10 builder-developers who have previously used ECMF were selected to be interviewed on their previous experiences with the program. The interviewees are the same selected group of participants for the A/B testing sessions. In addition to their experiences with ECMF, the demographic profile such as age, education, and experience level of the interviewees will be recorded. The demographic profile provides insights to "who" is using ECMF resources (McCoy et al., 2015).

Interview questions

The questions for the interviews have not been finalized yet but a few draft questions are listed below:

1. How were each of the resources utilized during the project?
2. What were the challenges of using ECMF resources?
3. Could you describe moments of enlightenment you had while using the resources?

The draft questions provided are expected to garner the experiences of builder-developers with ECMF tools and resources allowing for a better understanding of usability. It is of great importance to use the interview questions to create a narrative from the experiences of the interviewees during recording of the interviews.

Analysis of data

The data will be organized so that the interview questions and respective responses can be viewed appropriately and in a manner that is easy to comprehend in a matrix format (Saldana 2018). The participants' responses, feedback section, and interview transcripts will be coded using Dedoose, a qualitative analysis software. Initially descriptive coding will occur on the transcripts to condense the data. Next codes will be categorized into multiple themes which align with UX theoretical constructs. Data on the participants experience is analyzed using narrative analysis and focused coding based on thematical similarity.

Observations/Demonstrations

The process overview of the program manual shows the steps of the process to getting ECMF certification as shown in Figure 2. Due to the extensive amount of content in the manual, a navigability issue occurs when the user manually searches for desired information. The issue can be addressed by providing links to each of the steps in the process overview. The links connect the user with the desired sections of interest in the manual. Satisfaction and required task time for users of the program manual will be significantly affected by this improvement.

EarthCraft Multifamily Project Process

Process Overview

All EarthCraft Multifamily Developers and Technical Advisors must follow a specific project process in order to certify EarthCraft Multifamily projects. All steps of the process must be completed, including individual unit and building-level inspections, in order for a project to be eligible for certification. Each step in the EarthCraft project process is defined in detail on the following pages.

Pre-Construction	Pre-Drywall	Project Closeout
1 Project Registration	7 Kick-Off Meeting	13 Final Inspection(s)
2 Project Information Submittal	8 Kick-Off Meeting Report Submittal	14 Confirmed Energy Model(s)
3 Preliminary Energy Model(s) or Analysis of Prescriptive Compliance	9 Air Sealing Inspection(s)	15 Final Inspection Submittal
4 Preliminary Energy Model(s) Report Submittal(s) or Specifications reaching Prescriptive Compliance	10 HVAC Initial Diagnostics/Inspection(s)	16 Certification Submittal
5 EarthCraft Design Review	11 Insulation Inspection(s)	17 Certification
6 EarthCraft Design Review Report Submittal	12 Pre-drywall Inspection Submittal	

Figure 2. Process overview section of ECMF program manual

Hyperlink additions in the worksheet support the theory of using links to overcome navigability issues as shown in Figure 3. The hyperlink connects the user of the worksheet to the specific section of the program manual or technical guidelines to assist in the completion of the worksheet.

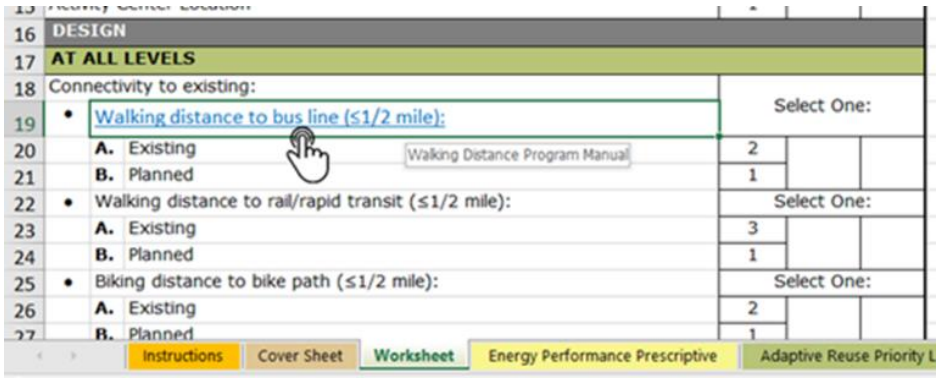


Figure 3. ECMF worksheet hyperlink to ECMF program manual

Font colors and sizes are also have significant impacts on the utilization of ECMF resources. Font colors and sizes appeal to users as they progress through tools and resources. With various font colors, such as red, the content within ECMF resources can be better distinguished to signify importance in the lengthy and wordy text. Appropriate font sizes can enhance users’ abilities to progress through ECMF tools and resources in a continuously fluent manner. Layout of information in the content-rich resources can assist in guiding users to optimal decisions by strategically presenting the content in an order of importance or significance as shown in Figure 4. The table of contents of the technical guidelines lists the sections to follow in accordance with the worksheet.

Table of Contents

Introduction	4
Site Planning	12
Site Design	
Site Preparation and Preservation Measures	
Alternative Transportation Accommodations	
Construction Waste Management	34
Resource Efficiency	38
Resource Design	
Advanced Framing Products	
Local, Recycled and/or Natural Content Materials	
Building Reuse	

Figure 4. ECMF technical guidelines table of contents

Choice architecture is best described as the multiple ways to present a choice to a decision-maker and the decision that is chosen depends on how the choice is presented (Johnson et al., 2012). Stakeholders can be nudged into making logical decisions by strategically framing content and options in EarthCraft resources. Seniority and years of experience are also expected to be factors that have contrasted impacts on the usability of resources. Preliminary findings of user experience studies have shown that seniority and years of experience have notable impacts on usability (Lallemand et al., 2015).

Interviews for this study have not been concluded yet. Preliminary findings suggest due to status quo bias and satisficing, builder-developers often adhere to the same routine when utilizing resources. Focused coding will show the most prominent theories represented within our data. The interview transcripts and codes occurring will be recorded in a code application analysis chart in Dedoose as shown in Figure 5. The figure shows how many times each code appears in each interview transcript. For example, a 1 means there is one instance of a specific code appearing in a transcript, a 2 means there are two instances of a specific code appearing in a transcript, and so on. Due to the complex nature of the codes being used, a complementary codebook will be created to provide the audience and future researchers with definitions and examples of all the codes used.

Media	Codes				Totals
	Design layout	Font color	Font size	Navigability	
Participant 1.docx	1		2	2	5
Participant 2.docx	1	1			2
Participant 3.docx	1	2	1	2	6
Participant 4.docx	3		1	1	5
Totals	6	3	4	5	

Figure 5. Code application analysis chart of interview transcripts and codes

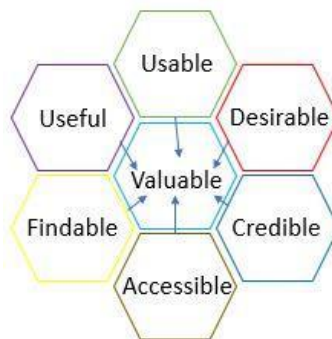


Figure 6. Structure of seven user experience features

CONCLUSIONS

The scope of this research study is intended to follow seven features of user experience: useful, usable, desirable, findable, accessible, credible, and valuable. The seven features of user experience are structured as shown in Figure 6 below. These features have been determined to be useful for analyzing the usability of green certification resources in sustainable construction. Preliminary analysis has shown that readability and navigation issues are present in ECMF tools and resources. Through choice architecture, appropriate content and options are strategically framed to improve accessibility of ECMF resources and enhance user decision-making.

Energy-efficient affordable housing has an influence that leaves imprints across multiple

sectors such as community diversity, health, and environmental sustainability. This research has the potential to provide intellectual merit by advancing our understanding of improving the delivery of green buildings using user experience methodologies. ECMF resources will need to lower the level of expertise required for sustainable infrastructure delivery to allow for the inclusion of a broader set of stakeholders. Improvements to ECMF tools and resources allow for inexperienced stakeholders to manage their roles in the project delivery process more effectively.

REFERENCES

- Blythe, M., Hassenzahl, M., Law, E., & Vermeeren, A. (2007). "An analysis framework for user experience (ux) studies: a green paper." *Towards a UX Manifesto COST294-MAUSE Affiliated Workshop*, 1–5.
- Clevenger, C. M., & Haymaker, J. (2006). "The Impact of the building occupant on abstract energy modeling simulations." Conference Proceedings, 10. Citeseer.
- Dixon, E., Enos, E., & Brodmerkle, S. (2011). "A/B testing of a webpage." US Patent.
- EarthCraft. (2018). "EarthCraft program manual 2018." Southface. (Feb. 15, 2019).
- Fellows, R. F., & Liu, A. (2015). *Research methods for construction*. John Wiley & Sons, Ltd.
- Johnson, E. J., Shu, S. B., Dellaert, B. G. C., Fox, C., Goldstein, D. G., Häubl, G., ... Weber, E. U. (2012). "Beyond nudges: tools of a choice architecture." *Marketing Letters*, 23(2), 487–504.
- Kantner, L., & Rosenbaum, S. (1997). "Usability studies of www sites: heuristic evaluation vs. laboratory testing." *Proceedings of the 15th Annual International Conference on Computer Documentation - SIGDOC '97*, 153–160.
- Lallemant, C., Gronier, G., & Koenig, V. (2015). "User experience: a concept without consensus? exploring practitioners' perspectives through an international survey." *Computers in Human Behavior*, 43, 35–48.
- McCoy, A. P., Agee, P., Adams, B., C. Theodore Koebel, Scott, S., Zhao, D., & Teni Ladipo. (2015). *The impact of energy efficient construction for lihtc housing in virginia*.
- Neal, T. S. (2010). "Green building for small residential contractors "perspectives of the earthcraft house program from residential homebuilders." 51.
- Nielsen, J. (1994). "10 usability heuristics for user interface design." <<https://www.nngroup.com/articles/ten-usability-heuristics/>> (Jul. 11, 2019).
- Nielsen, J. (1994). "How to conduct a heuristic evaluation." NN/g. (May 23, 2019).
- Norman, D. (2013). *The design of everyday things*. (Revised & Expanded Edition). New York, New York: Basic Books.
- Retzlaff, R. C. (2008). "Green building assessment systems: a framework and comparison for planners." *Journal of the American Planning Association*, 74(4), 505–519.
- Saldaña, J. (2018). "Coding and analyzing qualitative data." Johnny Saldaña. 179.
- Sengers, P. (2018). "Chapter 18 the engineering of experience." In *Funology 2: From Usability to Enjoyment* (pp. 287–299).
- Yin, R. K. (2017). *Case study research and applications: design and methods*. SAGE Publications.
- Zhao, D., McCoy, A., Agee, P., & Ladipo, T. (2016). "Impacts of housing technology and behavior on energy efficiency for affordable rental housing." 8.
- Zhao, D., McCoy, A. P., Du, J., Agee, P., & Lu, Y. (2017). "Interaction effects of building technology and resident behavior on energy consumption in residential buildings." *Energy and Buildings*, 134, 223–233.