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Data Visualization in the Public Energy Sector: A Study on User Experience and Satisfaction

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ABSTRACT

This study delves into the analysis of how data visualization impacts user experience (UX) when interacting with public electrical energy data. In the era of big data, the volumes of information on energy generation, distribution, and consumption are expanding exponentially. This surge underscores the urgency for presentation techniques that not only simplify complex datasets for the lay audience but also improve engagement and comprehension. Thus, the study aims to bridge the existing knowledge gap by identifying effective data visualization strategies that enhance the public's ability to understand intricate data, thereby supporting informed decision-making and heightening awareness about energy sustainability. Adopting a mixed-methods approach, the study integrates extensive literature reviews with empirical usability testing involving 30 participants. To complement the quantitative findings, qualitative insights were extracted from interviews and focus groups, aiming to capture user preferences, challenges encountered, and suggestions for improvement. This analysis covered the effectiveness of various visualization components, including filters, information hierarchies, graphical elements, and data diversity, in facilitating an intuitive grasp of electrical energy data. The study showed a correlation between intuitive visualization techniques and the improvement of UX metrics such as engagement, comprehension, and satisfaction. Key findings emphasized that features such as interactive filters and good information hierarchies are instrumental in empowering users to effectively navigate and interpret electrical energy data. The study culminates in the formulation of eleven targeted guidelines for the development of user-centric data visualizations within the public energy sector.

Keywords: Data visualization, Human factors, Cognitive psychology, User experience, Public energy data

INTRODUCTION

In the contemporary landscape marked by the continuous proliferation of data, the quantity of accessible information is unparalleled. This phenomenon is particularly pronounced in sectors where public data influences social decision-making and awareness, such as the energy sector. Herein, data pertaining to energy generation, distribution, and consumption is not only voluminous but complex, posing a challenge for the lay audience to comprehend without the aid of effective presentation strategies (Tufte,

1997; Few, 2009). The complexity accentuates the need for advanced data visualization techniques that refine intricate datasets, thereby augmenting public engagement and comprehension. Data visualization transcends mere aesthetic presentation; it emerges as a facilitator of user experience (UX), enabling informed decision-making and raising awareness on critical matters like energy sustainability (Cairo, 2012; Yau, 2013).

The present study explores de impact of data visualization's on UX, specifically in the context of interactions with public energy data. The study is dedicated to identifying data visualization strategies that increase the public's capability to understand complex public energy data. Concentrating on UX metrics such as engagement, comprehension, and satisfaction, the research endeavors to discover insights on optimizing data visualization to foster public understanding and participation in energy sustainability dialogues.

Employing a mixed-methods approach, the research integrates an extensive literature review with an empirical usability testing involving thirty participants (Nielsen, 1993; Shneiderman, 1996). This methodology facilitates a thorough exploration of the influences exerted by various data visualization elements—such as filters, information hierarchies, graphical elements, and data diversity—on user satisfaction and engagement (Lentez, 2020). Through interactive sessions of usability testing with existing data visualization dashboards displaying electrical energy datasets, performance was measured using task completion times, error rates, and subjective usability scores derived from questionnaires. Complementing these quantitative findings, qualitative insights were extracted from interviews and focus groups, in order to identify user preferences, encountered challenges, and recommendations for improvement of the dashboards.

This methodical approach not only elucidates the efficacy of diverse visualization components in enabling an intuitive comprehension of electrical energy data but also highlights the role of user-centered design in devising data visualizations for the public sphere (Lentez, 2020). By bridging the gap between complex datasets and the general population, well-conceived data visualizations hold the potential to promote the discourse on energy issues. Thus, the study contributes to the burgeoning domain of data visualization by furnishing academically and practically pertinent insights, guiding future design initiatives to resonate with user needs and preferences more closely in the realm of public energy data (Norman, 2004; Zimmerman, Forlizzi, & Evenson, 2007).

DATA VISUALIZATION AND PUBLIC DATA

Data visualization is a critical tool in making complex information accessible and understandable to a broader audience. As noted by Tufte (1997), effective visualization helps users analyse and reason about data and information graphically. According to Fry (2008), visualization serves as a translation between the abstract and complex data into a form that human senses can understand and interact with, thereby supporting decision-making processes.

The role of interactive data visualization is increasingly emphasized in literature, particularly in how it facilitates deeper engagement with data.

Shneiderman's (1996) visualization mantra —"overview first, zoom and filter, then details-on-demand"— highlights the importance of providing users with intuitive navigation and interaction mechanisms to explore complex datasets efficiently.

In this context, cognitive ergonomics plays a significant role in the design of data visualizations by focusing on the human factors that influence information processing. As outlined by Norman (2004), the cognitive and emotional responses of users to visualization interfaces can significantly impact their satisfaction and overall experience. Ergonomic principles ensure that visualizations are not only functional but also address the psychological and cognitive needs of users, promoting ease of use and reducing cognitive load (Wickens et al., 2004).

As such, the usability of data visualizations is directly linked to user satisfaction and effectiveness in data interpretation and, therefore, to its UX. As suggested by Nielsen (1993), usability encompasses attributes such as learnability, efficiency, memorability, errors, and satisfaction. High usability in data visualization ensures that users can interact with data without undue frustration and with increased productivity, which is crucial in environments like public energy data where decisions based on these visualizations can have extensive implications when used by public managers.

Data visualizations in the public sector, therefore, must not only be accurate but also designed with the lay public in mind, ensuring that information is presented clearly and can be interpreted correctly without specialized knowledge.

METHODOLOGY

This study employs a mixed-methods approach, integrating both quantitative and qualitative methodologies to investigate the impact of data visualization on user experience, specifically in the context of interacting with public electrical energy data (Lentez, 2020). This approach is necessary for exploring the multifaceted nature of data visualization's influence on user comprehension, engagement, and satisfaction (Creswell & Creswell, 2017). The methodology encompasses an extensive literature review, usability testing, and the extraction of qualitative insights through interviews and focus groups.

An extensive literature review constituted the initial phase of the research, aiming to identify existing knowledge gaps in the domain of data visualization and its effects on user experience. The review focused on scholarly articles, books, and case studies pertaining to data visualization, user experience design, and the specific context of public electrical energy data.

The empirical study involved a purposive sample of 30 participants, selected to encompass a diverse range of experiences with data visualization tools. This sample included 15 participants identified as data visualization specialists, possessing expertise in the field, and 15 non-specialists, representing the lay audience likely to interact with public electrical energy data visualizations. The inclusion of both specialist and non-specialist

participants allowed for a comprehensive exploration of data visualization strategies from multiple perspectives (Palinkas et al., 2015).

Usability testing sessions were conducted to quantitatively assess the effectiveness of various data visualization components, including filters, information hierarchies, graphical elements, and data diversity. Participants interacted with interactive dashboards displaying public energy datasets, and their performance was measured using task completion times, error rates, and subjective usability scores obtained from questionnaires (Lentez, 2020). This method allowed for the objective evaluation of visualization techniques in facilitating user comprehension and navigation of complex datasets (Nielsen, 1993).

To complement the quantitative findings from usability testing, qualitative data were collected through semi-structured interviews and focus groups (Morgan, 1997). These discussions aimed to capture participants' preferences, challenges encountered during the usability tests, and suggestions for enhancing the data visualization dashboards. The qualitative insights provided depth and context to the quantitative results, offering a holistic understanding of the user experience with public energy data visualizations.

Quantitative data from usability tests were analysed statistically to identify significant patterns and correlations between visualization techniques and UX metrics. Qualitative data from interviews and focus groups were subjected to thematic analysis, enabling the identification of recurring themes related to user preferences, challenges, and recommendations for data visualization improvements. This dual analysis approach ensured a comprehensive examination of the study's research questions (Braun & Clarke, 2006).

RESULTS

The usability testing conducted as part of this research offers a deep insight into how data visualization strategies influence user experience (UX) when interacting with public energy data. Participants included 15 data visualization specialists and 15 non-specialists, allowing for an analysis of both expert and lay user interactions with public energy data dashboards.

The quantitative findings reveal significant disparities in task success rates and interaction times between specialists and non-specialists. For specialists, the task completion success rate averaged at 80%, whereas for non-specialists it was slightly lower, indicating the complexity of the visualizations used and their varying accessibility to different user groups (Lentez, 2020).

The average task completion time for specialists was noted to be approximately 2 minutes and 30 seconds, significantly faster than the 3 minutes and 15 seconds recorded for non-specialists. This suggests that familiarity with data visualization concepts positively impacts the efficiency of data interaction.

Satisfaction, measured through post-interaction surveys, indicated a generally positive response with some notable exceptions. While specialists expressed high satisfaction rates, scoring an average of 4.2 out of 5 in

terms of ease of use and data comprehension, non-specialists reported lower satisfaction, averaging 3.5 out of 5. This highlights a gap in visualization design, underscoring the need for more intuitive interfaces that can cater effectively to a broader audience (Lentez, 2020).

Qualitative data collected from interviews and focus groups shed light on specific elements that affected user satisfaction. Participants frequently cited the presence of interactive filters and a clear hierarchy of information as crucial for enhancing their understanding and engagement with the data. Graphical elements such as dynamic charts and maps were praised for their ability to illustrate complex data in an accessible format. However, some users noted the lack of contextual information and guidance on how to interpret the data effectively.

The analysis confirmed that intuitive design features such as interactive filters, graphical diversity, and clear informational hierarchies substantially improve user satisfaction and engagement.

The performance metrics (task completion time and error rates) correlated strongly with user satisfaction, indicating that more efficient interfaces lead to higher user contentment and better overall UX.

These results demonstrate the significant role of tailored visualization strategies in enhancing the public's ability to interact with and understand complex public energy data. The findings also highlight the necessity for design adjustments to accommodate non-specialist audiences, ensuring that public data visualizations are inclusive and effectively serve their educational and informational purpose.

DISCUSSION

The investigation into the influence of data visualization on user satisfaction, particularly within the public electric sector, reinforce the important role of user-centered design principles. The mixed-methods approach, combining extensive literature review and empirical usability testing, facilitated a comprehensive understanding of how various data visualization components — filters, information hierarchies, graphical elements, and data diversity — affect user experience (UX).

Influence of Visualization Components on UX

The study's quantitative findings reveal a significant correlation between the intuitiveness of visualization strategies and UX metrics improvement, including engagement, comprehension, and satisfaction. This aligns with previous research emphasizing the importance of interactive and intuitive design in data visualization for enhancing user interaction with complex datasets (Nielsen, 1993; Shneiderman, 1996). Notably, interactive dashboards, dynamic charts, and graphical summaries significantly outperformed traditional tabular presentations, echoing the authors such as Cairo (2012) and Yau (2013) regarding the efficacy of visually compelling data presentations in boosting user engagement and comprehension.

Qualitative insights from interviews and focus groups further corroborated these findings, highlighting user preferences for visual cues and interactive exploration capabilities that cater to individual needs and preferences.

Implications for Public Discourse on Energy Issues

The findings reinforce the role of sophisticated data visualization techniques in elevating public discourse on energy issues. By demystifying complex datasets related to energy generation, distribution, and consumption, well-designed visualization, such as dashboards, can significantly enhance public engagement in discussions about energy sustainability. This is particularly relevant in the context of growing environmental concerns and the urgent need for informed public participation in sustainable energy initiatives.

Eleven Guidelines for User-Centric Data Visualization Development

This research has identified several key factors that impact user satisfaction in the interaction with public electrical energy data visualizations. Based on the empirical usability testing and comprehensive analysis, eleven targeted guidelines (Lentez, 2020) are proposed for the development of future user-centric data visualizations in the public energy sector. These guidelines aim to facilitate the design of intuitive, engaging, and informative visualizations that cater to a diverse user base, including both specialists in data visualization and the lay audience.

1. Incorporate Interactive Filters: Allow users to customize their data exploration experience through interactive filters. This empowers users to focus on data that are relevant to their specific interests or concerns, enhancing their overall engagement and satisfaction (Nielsen, 1993).
2. Implement Clear Information Hierarchies: Design visualizations with clear information hierarchies to guide users effortlessly through complex datasets. A logical structure aids in the intuitive understanding and navigation of the information presented.
3. Utilize Diverse Graphical Elements: Employ a variety of graphical elements (e.g., charts, graphs, maps) to represent different data types and relationships. This diversity in presentation helps cater to different user preferences and enhances the interpretability of data (Tufte, 1997).
4. Ensure Data Diversity: Present a wide range of data to offer comprehensive insights into the electrical energy sector. This includes historical data, real-time statistics, and projections, catering to both casual users and experts seeking depth.
5. Optimize for Usability: Adhere to best practices in usability to ensure that the visualization is easy to use, learn, and navigate. This involves minimizing the cognitive load and providing immediate, meaningful feedback to user interactions (Norman, 2004).
6. Design for Accessibility: Make visualizations accessible to users with diverse abilities by following accessibility guidelines. This includes considering color contrasts, providing text alternatives for graphical information, and ensuring keyboard navigability.

7. Enable Interactive Exploration: Facilitate interactive exploration of data, allowing users to drill down into specifics or zoom out for an overview. Interactive elements should be responsive and provide immediate feedback.
8. Support Multiple User Pathways: Recognize that users may have different goals and levels of expertise. Design visualizations that support multiple pathways through the data, accommodating both novice users and experts.
9. Provide Contextual Help and Documentation: Include contextual help and documentation within the visualization. This assists users unfamiliar with the data or the visualization tool, enhancing their learning and engagement.
10. Incorporate User Feedback in Design Iterations: Engage with your user base to gather feedback on the visualization. User insights should inform ongoing design iterations, ensuring the tool evolves in alignment with user needs and preferences.
11. Evaluate and Refine Based on User Testing: Conduct regular user testing sessions to evaluate the effectiveness of the visualization tool. Use insights from these evaluations to refine and improve the design and functionality of the tool.

CONCLUSION

This study explored how data visualization impacts user experience (UX) in the interaction with public energy data. The mixed-methods research approach, encompassing an extensive literature review and empirical usability testing with thirty participants, has highlighted the role of intuitive visualization techniques in enhancing UX metrics such as engagement, comprehension, and satisfaction.

The quantitative analysis underscored the efficacy of advanced visualization, such as interactive dashboards and dynamic charts, in facilitating user interaction with complex public energy data. These tools were shown to significantly outperform traditional tabular presentations in terms of task completion times, error rates, and subjective usability scores. The qualitative insights, drawn from interviews and focus groups, echoed the quantitative findings, highlighting the users' preference for visualization features that enable effective navigation and interpretation of data.

Key to this study's findings is the formulation of eleven targeted guidelines for developing user-centric data visualizations within the public energy sector. These guidelines emphasize the importance of features like interactive filters, clear information hierarchies, and the inclusion of graphical elements and data diversity. Such features are instrumental to facilitate users to navigate and interpret complex datasets confidently.

FUTURE DIRECTIONS

Looking forward, this research opens several pathways for further exploration in the domain of data visualization and UX in public energy data interaction. The following future directions are proposed:

1. Expanding User Studies: Future studies could extend the participant base to include a wider demographic range, capturing a more diverse set of user experiences and preferences. This could help in refining the guidelines for user-centric design further.
2. Longitudinal Studies: Investigating the long-term effects of using advanced data visualization representations on user engagement and satisfaction would provide deeper insights into the sustained value of these visualizations.
3. Cross-Sectoral Applications: Exploring the application of the identified guidelines in other public sectors, such as water management or public transportation, could reveal universal principles of effective data visualization design.
4. Technological Advances: As technology evolves, so do the opportunities for innovative data visualization techniques. Future research could explore the integration of emerging technologies like virtual reality (VR) and augmented reality (AR) in public data visualization.
5. Policy and Practice Implications: Further research could examine how the findings of this study can influence policy-making and practical implementations in the public energy sector to foster informed public discourse and participation.

In conclusion, by bridging the gap in existing literature regarding the confluence of data visualization and UX in the electrical energy data sphere, this investigation provides profound insights into creating more accessible and impactful public data interfaces. The enhanced public engagement, informed decision-making, and heightened sustainability consciousness underscore the significant impact of data visualization on augmenting UX with public electrical energy data. This study contributes to the field of data visualization by offering academically and practically relevant insights, guiding future design efforts to align more closely with user needs and preferences in the context of electrical energy data.

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