IOP Conference Series:
Earth and
Environmental Science

PAPER • OPEN ACCESS

Key Elements of Trust in Building Renovation Data Management: A Usability Study of a Centralized Platform

To cite this article: Philipp Zielke and Svenja Lauble 2025 *IOP Conf. Ser.: Earth Environ. Sci.* **1546** 012077

IOP Conf. Series: Earth and Environmental Science **1546** (2025) 012077 doi:10.1088/1755-1315/1546/1/012077

Key Elements of Trust in Building Renovation Data Management: A Usability Study of a Centralized Platform

Philipp Zielke[1]*, Svenja Lauble[1]

[1] Institute of Technology and Management in Construction, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

*E-mail: philipp.zielke@kit.edu

Abstract. The urgent need for building renovation is growing, yet the availability of machine-readable data remains limited, hindering the decision-making process for building owners. This paper addresses this gap by identifying key elements in document digitization, data enrichment, and data analysis that are essential to fostering trust in data processing. To address this, we developed a mock-up based on design thinking principles that aims to consolidate existing building information into a central, accessible location. This platform provides users with a comprehensive overview of building data. We conducted a user study with 44 participants to evaluate the usability of the platform using the System Usability Scale (SUS). The results showed a high SUS score, reflecting strong usability and positive feedback. Participants highlighted the value of centralizing building data, which significantly supports renovation decision-making. The results underscore the platform's potential to drive digital transformation in the building sectors, marking a critical step forward in renovation planning.

1. Introduction

The renovation of existing buildings plays a crucial role in the realization of energy efficiency and sustainability objectives as the construction industry is responsible for 38% of emissions in 2019 [1]. In Europe, a significant proportion of the building stock was constructed prior to 1980, a time before the introduction of modern energy regulations such as the Building Energy Act [2]. This has resulted in a high demand for renovation today, yet the availability of reliable building data, like the floor area of the building or year of construction, remains limited making the renovation planning process more complicated. When data is available, it frequently exists in a non-digital format and is dispersed across multiple sources, often failing to accurately reflect the current state of the buildings [3]. The trustworthiness of building data is a pivotal factor in enhancing the efficacy of renovation planning [4], as inaccurate or outdated information can result in inefficient planning and increased costs [5, 6]. The ability to verify and update building information is therefore crucial for fostering trust in renovation data management.

This paper explores how a user-centered, centralized platform can address these challenges by improving data reliability and usability. It investigates the key elements of trust in building renovation data management, examining how a usability-driven approach can enhance confidence in centralized data platforms. To address this question, a usability study was conducted, evaluating user interactions with a prototype platform. The study aims to identify critical design principles that improve data reliability, user engagement, and overall trust.

The paper is structured as follows: Section 2 provides an overview of extant research on trust in digital platforms and data management. Section 3 presents the case study, detailing the usability evaluation process. Section 4 discusses the findings, and Section 5 concludes with key takeaways and future research directions.

2. State of the art

2.1 Trustworthy data platforms in the construction industry

The construction industry is confronted with substantial challenges in the management and integration of building data, attributable to the heterogeneity of data sources and the variability of data formats [3]. Existing digital platforms aspire to centralize and streamline data access; however, they frequently encounter interoperability and usability issues. An example of such a platform is TABULA, which offers structured data on building typologies and energy performance. Nevertheless, TABULA necessitates manual data entry and discrete analyses, impeding its efficacy in automated decision-making processes [7].

A significant challenge in the development of data platforms in general is the establishment of trust in the provided information [8]. Trust can be defined as the willingness of a party to be vulnerable to the actions of another party based on the expectation that the latter will perform a particular action important to the former, irrespective of the ability to monitor or control that party [9]. While this concept originates from interpersonal relationships, the term trust was expanded to how individuals interact with technological systems [10]. To cultivate trust in digital data platforms, aspects such as data protection, availability, and quality assume a pivotal role [11]. The heterogeneity of data sources in the construction sector, coupled with the incessant growth in data volume poses a significant challenge to the efficient management, processing, and analysis of data. Especially in planning processes when renovating buildings, trust in data is important as high-quality data “can facilitate accurate decision-making” [12]. At the same time a general lack of trust in the construction industry, makes it difficult to build trust into new digital systems [13]. Research has shown that centralized data platforms can improve trust by offering a single, reliable source of information rather than fragmented datasets spread across multiple systems [14]. In addition, transparency mechanisms such as data provenance tracking and user feedback systems contribute to higher perceived reliability and engagement [15].

2.2 User-centric design

In the context of developing new ideas, products or other soultions, usability emerges as a pivotal factor in fostering trust among users [16]. Research findings suggest that individuals are more inclined to interact with systems that offer intuitive navigation, clear data visualization, and interactive feedback mechanisms [17]. Jakob Nielsen's usability heuristics [18] underscore the significance of factors such as visibility, error prevention, and user control, which collectively contribute to heightened trust levels in digital platforms. Advancements in user-centered design have further enhanced digital platforms by incorporating iterative design processes that involve direct user feedback [19]. This aligns with the Design Thinking (DT) approach, which emphasizes empathy-driven problem-solving and iterative prototyping to refine platform usability [20]. Therefore the DT approach was applied in this paper.

3. A centralized platform

3.1 Methodical approach

To investigate the usability of a centralized platform for building renovation data management, a clickable prototype (a so-called "mock-up") was developed. A mock-up is defined as an exemplification of a system that is intended to provide the user with a general impression of the planned system, albeit without the functionality of said system. [21] The design process followed the DT approach, ensuring user involvement at every step. DT has emerged as a pervasive approach for addressing complex problems and catalysing creative innovation processes within organizations and therefore was chosen as a methodical approach [22]. The problem-solving process involves people as well as business and technological factors. The driving force for the emergence of DT was the difficult collaboration in creative processes within project teams when the participants came from different disciplines. This problem is solved through a process in which a common starting point is created for all participants, which leads to collaborative knowledge generation and solution finding. [20] In this study, the five-stage approach of DT according to [23] was applied (Figure 1) and used in three development phases. This iterative approach integrated user feedback at each step, improving usability and aligning the platform with user needs.

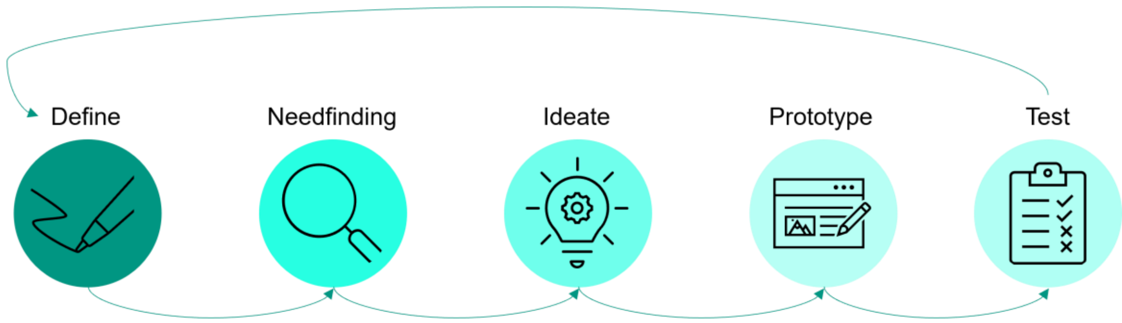

Figure 1. Design thinking cycle according to [23]

In the first development phase of the DT cycle a user flow was created which was then transformed into a wireframe in the second iteration phase and finally into a mock-up. The final mock-up was created using the software Figma and served as proof of concept for a platform that consolidates building data from multiple sources into a single, accessible location. Figure 2 exemplary shows the three development phases.

After developing the mock-up, a usability study was conducted to evaluate the effectiveness of it. The study was conducted from July 9, 2024, to August 7, 2024, using a two-phase approach: usability testing with the tool Maze and a following standardized questionnaire based on the System Usability Scale (SUS) by Brooke [24]. Participants were asked to complete predefined tasks within the mock-up and then rate their experience using the SUS questionnaire. To complement the quantitative data, an open discussion round was held to gather qualitative insights into specific usability and trust aspects.

IOP Conf. Series: Earth and Environmental Science **1546** (2025) 012077 doi:10.1088/1755-1315/1546/1/012077

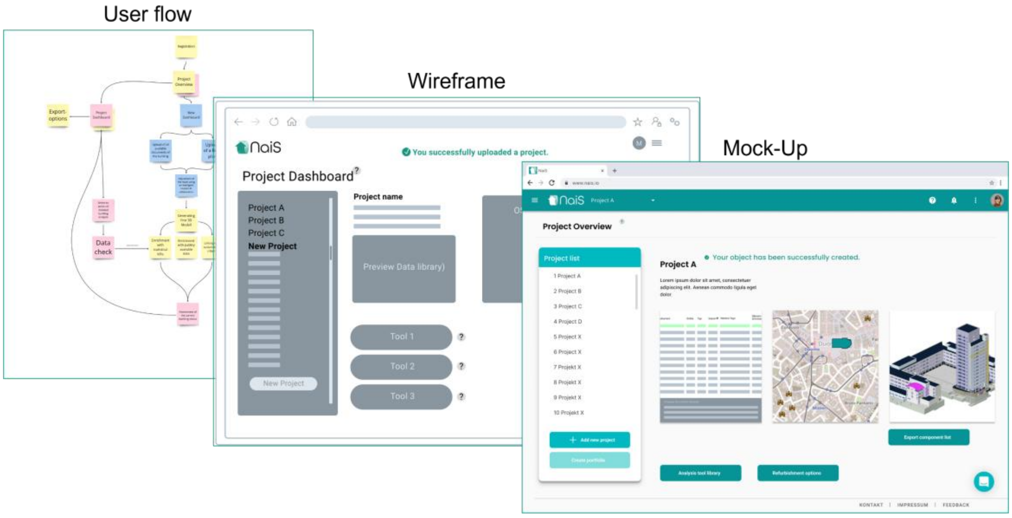

Figure 2. Illustration of the three development phases: user-flow, wireframe, mock-up (from left to right)

The SUS is a widely used tool for assessing the usability of a system [26]. It consists of 10 standardized questions, each rated on a 5-point Likert scale (from 1 = strongly disagree to 5 = strongly agree). The questions alternate between positive and negative statements, covering aspects such as ease of use, system complexity, and confidence in usage (Table 1).

Table 1. Overview of the SUS questionnaire [24]

Statement
1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I though the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

The SUS score ranges from 0 to 100, with higher scores indicating higher perceived usability [24]. Scores above 68 are generally considered above average, and scores of 80 and above are typically classified as excellent [25]. While the SUS principally measures usability, prior research has demonstrated that usability is a foundational component of trust in digital tools [26, 27]. A high SUS score indicates that users perceive the system as intuitive, transparent, and controllable. These characteristics are all significant importance in the development of trust, especially among non-expert users [28].

A total of 44 participants were included in the study, with an average age of 38 years (ranging from 21 to 63). Participants were recruited via social media channels and through partners from the researchers' immediate professional network. The participants were divided into two test groups: one consisting of members from the project consortium (10 participants) and the rest of the 34 participants recruited through newsletters, social media, and direct contacts. The participants represented a variety of professional backgrounds, including property managers, construction industry professionals, and software developers. The "other" category, which included individuals from research institutions, accounted for 32% of the sample. A total of eight out of 44 participants did not complete the SUS questionnaire or the usability test.

3.2 Description of the platform

The primary objective of the platform is to facilitate the decision-making process for the renovation of existing buildings by centralising data. The tool is designed for use by portfolio managers and municipal administrators who wish to make renovation decisions for their building stock based on reliable information. To address the challenge posed by fragmented and unstructured data, the platform integrates an AI-driven approach to the extraction of relevant information from text and image documents, including energy certificates, building assessments and layout plans. Important data points are defined as: General building type, year of construction of the building, year of installation of the heating system, as well as the conditioned net floor area (in m^2) for non-residential buildings and the usable floor area (in m^2) for residential buildings. In a first step, floor plans are processed using a segmentation algorithm that identifies the three elements: walls, windows and doors. Based on this analysis, an initial digital model is created. The reliability of the extracted information is ensured by means of a human-in-the-loop validation process, the purpose of which is to minimise the occurrence of AI hallucinations and to guarantee the plausibility of the data. The results of this process are transferred into an IFC (Industry Foundation Classes) model, which is then linked with public databases such as TABULA to incorporate sustainability factors and standardized building typologies. With this consolidated and verified dataset, the platform enables users to generate preliminary assessments of renovation potential and the prioritization of interventions across their building portfolio.

3.3 Results of the usability study

A usability study was conducted to ascertain the platform's perceived benefits and areas for improvement. Based on the qualitative feedback from participants and thematic coding of their responses in the open discussion, the following elements were identified as most relevant for building trust (in descending order of importance):

1. Transparency and clarity of data quality indicators
   Nearly all participants emphasized the importance of understanding the quality of the presented data. The traffic light system was positively received as a quick indicator, but many expressed a desire for more detailed insights—particularly when data was flagged as suboptimal. Suggestions included augmenting the system with percentage values, scalable ratings, and clearer explanations of how benchmarks were calculated.

2. Comprehensibility and interface clarity
   Many participants described the platform as "easy to understand," "clear," and "well-structured." This strong positive feedback underlines that an intuitive layout plays a fundamental role in building user trust—especially among those less experienced with digital renovation tools.
3. Automation and reduced manual effort
   Participants appreciated the automated analysis of building data, particularly as it enabled quick initial assessments without the need for manual document review. However, the perceived trustworthiness of automation was closely tied to transparency: users expect automated processes to be both accurate and explainable. The human-in-the-loop validation—where professionals correct or verify AI-generated results—was seen as an important safeguard.
4. Guided workflows and usability
   The structured process flow and interface features like a continuous progress bar contributed positively to user experience and trust. These elements helped users feel oriented and in control.

To systematically evaluate the usability of the platform, SUS was employed. The results of the study (Table 2) demonstrate that the platform achieved a strong usability rating, with an overall SUS score of 76.53. Internal users from the project team rated the platform slightly higher (79.75) compared to external participants (75.29). Furthermore, the absence of a significant correlation between age and perceived usability (correlation coefficient: 0.01) suggests that the platform's usability remained consistent across different age groups.

Table 2. Results of the SUS questionnaire

Group	Average SUS Score	Standard Deviation	1st Quartile	Median	3rd Quartile	Correlation Age/SUS
Project group	79.75	13.62	70.63	83.75	90	-0.25
External Participants	75.29	14.18	68.75	75	85	0.13
Total	**76.53**	**14.37**	**69.83**	**77.5**	**87.5**	**0.01**

Beyond the issue of usability, participants provided detailed feedback in the discussion round on the perceived value of the platform, with a frequently mentioned benefit being the ability to quickly assess the condition of a building. This ability helps to identify optimization potential and facilitate informed decision-making during the early stages of renovation planning. Users also expressed appreciation for the centralization and integration of data, which eliminates the need to manually collect and merge energy-related datasets from multiple sources. The automated data processing capabilities of the platform were identified as a notable advantage, as they reduce manual workload and facilitate seamless integration into analytical workflows, such as life cycle assessments and reuse potential.

4. Discussion

A primary limitation of the present study is the relatively limited sample size and the heterogeneity of the participants. With a total of 44 test users, the study offers preliminary insights into the usability of the platform and the perceived benefits to the users. However, the relatively small sample size limits the generalizability of the findings, particularly considering the diverse professional backgrounds of the participants. While the heterogeneity of the sample is beneficial for obtaining broad feedback, it also raises the question of whether a more targeted approach would be beneficial. Given that property managers are among the primary stakeholders of the platform, focusing the study specifically on this user group could provide more precise insights into their specific needs and challenges. A more homogeneous sample could help refine key functionalities and ensure that the platform fully meets the requirements of its core users.

A comparison of the developed platform with existing platforms such as TABULA reveals significant advancements in data integration and usability. While TABULA provides valuable reference data on building typologies and energy performance, it requires manual data entry and separate analysis [7]. In contrast, the developed platform automatically consolidates building data from multiple sources into a single, accessible interface with an improved usability.

5. Conclusion and outlook

The developed platform mock-up shows the potential of an improvement in the renovation planning process, achieved by centralizing building data and providing an intuitive user interface. The use of design thinking principles from the initial design stage ensures a user-centered approach. A mentioned feature of the developed platform mock-up is its user-friendly interface, particularly the integration of interactive visualization. The conducted usability study revealed that users found the interface intuitive and easy to navigate, suggesting that the platform effectively addresses the common challenges of existing databases, such as complexity and limited accessibility for non-experts. The high SUS score reflects the platform's strong usability and positive user feedback. Finally, participants appreciated the platform's ability to consolidate data from multiple sources, automate data processing, and support renovation decision-making.

Future research should prioritize the expansion of the platform's capabilities, such as enhancing AI-driven features, refining data quality indicators and addressing user concerns regarding AI transparency. Through continuous refinement of the platform based on user feedback, it has the potential to become an indispensable tool for the building renovation sector, promoting digital transformation and supporting sustainable development goals.

Acknowledgements
The authors acknowledge the financial support by the Federal Ministry for Economic Affairs and Climate Action of Germany in the project with the project number 01MN23005. The generative AI tool OpenAI ChatGPT (2025) was used in the research and the drafting of the manuscript.

References

[1] United Nations Environment Programme (UNEP) and Global Alliance for Buildings and Construction (GABC) 2020 Global status report for buildings and construction. https://wedocs.unep.org/20.500.11822/34572 (accessed 12 February 2025).
[2] Metzger S, Jahnke K, Walikewitz N, Otto M, Grondey A, & Fritz S 2019 *Wohnen und Sanieren* Empirische Wohngebäudedaten seit 2002
[3] Lauble S, Bonekämper H, Zielke P, Wu B 2024 *15th European Conference on Product & Process Modelling*

[4] Sun Y and Gu Z 2022 'Using computer vision to recognize construction material: A Trustworthy Dataset Perspective', *Resources, Conservation and Recycling*, 183, p. 106362. Available at: https://doi.org/10.1016/j.resconrec.2022.106362.
[5] Liu Y *et al.* 2023 'A high-quality dataset construction method for text mining in materials science', *Acta Physica Sinica*, 72(7), p. 070701. Available at: https://doi.org/10.7498/aps.72.20222316.
[6] Ekström T. *et al.* (2021) 'Evaluating the impact of data quality on the accuracy of the predicted energy performance for a fixed building design using probabilistic energy performance simulations and uncertainty analysis,' Energy and Buildings, 249, p. 111205. https://doi.org/10.1016/j.enbuild.2021.111205.
[7] Institute for Housing and Environment 2011 TABULA WebTool - User Guide. Available at: https://episcope.eu/fileadmin/tabula/public/docs/TABULA_WebTool_UserGuide.pdf (Accessed: 28.02.2025).
[8] Weber-Lewerenz B and Traverso M 2023 Best Practices im Bauwesen 4.0 – Katalysatoren digitaler Innovationen/Best Practices in Construction 4.0 – Catalysts for digital Innovations (Part I) Bauingenieur, 98(05), 163–171.
[9] Mayer, R. C., Davis, J. H., & Schoorman, F. D. 1995 An Integrative Model of Organizational Trust *The Academy of Management Review*, *20*(3), 709–734. Available at: https://doi.org/10.2307/258792
[10] Hoff K. A., & Bashir M. 2015 Trust in automation: integrating empirical evidence on factors that influence trust. *Human factors*, *57*(3), 407–434. Available at: https://doi.org/10.1177/0018720814547570
[11] Meurisch C and Mühlhäuser M 2022 Data Protection in AI Services: A Survey. *ACM Computing Surveys, 54(2)*, 1–38. Available at: https://doi.org/10.1145/344075
[12] Altendeitering M 2023 Design principles for data quality tools *PhD Thesis* TU Dortmund, Dortmund
[13] Surakka T 2006 Knowledge as a business opportunity knowledge transfer practices in Finnish AEC industry networks. in M Maula, M Hannula, M Seppä & J Tommila (eds), *ICEB + eBRF 2006, Tampere, Finland, 28.-11-2.12.2006.* Tampere University of Technology : University of Tampere, Tampere.
[14] Meeßen S.M., Thielsch M.T. and Hertel G 2020 'Trust in Management Information Systems (MIS): A Theoretical Model', *Zeitschrift für Arbeits- und Organisationspsychologie A&O*, 64(1), pp. 6–16. Available at: https://doi.org/10.1026/0932-4089/a000306.
[15] Jain N (2025) 'Enhancing Data Integrity through Provenance Tracking in Semantic Web Frameworks'. arXiv. Available at: https://doi.org/10.48550/ARXIV.2501.09029.
[16] Zhang B, Dong N, & Rischmoller L 2020 Design Thinking in Action: A DPR Case Study to Develop a Sustainable Digital Solution for Labor Resource Management *28th Annual Conference of the International Group for Lean Construction (IGLC)* (pp. 25–36). Available at: https://doi.org/10.24928/2020/0137
[17] Norman D 2013 *The design of everyday things: Revised and expanded edition*
[18] Nielsen J 1994 *Usability Engineering*
[19] Brown T 2009 *Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation*
[20] Plattner H., Meinel C, Leifer L (2016) *Design Thinking Research*. Cham: Springer International Publishing (Understanding Innovation).
[21] Link P *et al* 2020 'The Design Thinking Toolbox: A Guide to Mastering the Most Popular and Valuable Innovation Methods'.
[22] Dell'Era C *et al* 2020 'Four kinds of design thinking: From ideating to making, engaging, and criticizing', *Creativity and Innovation Management*, 29(2), pp. 324–344. Available at: https://doi.org/10.1111/caim.12353.
[23] Uebernickel F *et al* 2015 *Design Thinking*. Frankfurt: Frankfurter Allgemeine Buch (Business book summary).
[24] Brooke J. 1996 'SUS: A "Quick and Dirty" Usability Scale', pp. 207–212. Available at: https://doi.org/10.1201/9781498710411-35.
[25] Sauro J and Lewis J R 2012 *Quantifying the User Experience*. Elsevier. Available at: https://doi.org/10.1016/C2010-0-65192-3.
[26] Acemyan C. Z. & Kortum P. 2012 The Relationship Between Trust and Usability in Systems *Proceedings Of The Human Factors And Ergonomics Society Annual Meeting*, *56*(1), 1842–1846. Available at: https://doi.org/10.1177/1071181312561371
[27] Salanitri D. *et al.* 2015b 'Relationship between trust and usability in virtual environments: an ongoing study,' in *Lecture notes in computer science*, pp. 49–59. Available at: https://doi.org/10.1007/978-3-319-20901-2_5.
[28] Hoff K. A. & Bashir M 2014 Trust in automation *Human Factors The Journal Of The Human Factors And Ergonomics Society*, *57*(3), 407–434. Available at: https://doi.org/10.1177/0018720814547570