

THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Practice Perspectives on Digital Assessment Tools for Sustainable Building Design

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden, 2026

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ISBN 978-91-8103-466-0

Doktorsavhandlingar vid Chalmers tekniska högskola, Ny serie nr 5923.

ISSN 0346-718X

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Cover:

Matrix representation of actor interactions in a sustainable building design project.

Textile interpretation by Henny von Schantz.

Typeset by the author using $\text{\LaTeX}$. All figures by the author, unless otherwise stated. Cover art by Henny von Schantz.

Printed by Chalmers digitaltryck

Gothenburg, Sweden 2026

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Abstract

Digital tools for building sustainability assessment (BSA) can help architects manage social and environmental impacts of buildings, but existing tools see little use in design practice. Where previous research has emphasised the usability of tool interfaces for the individual practitioner, this thesis instead explores how tool usefulness can be understood through the relational context of design practice. The thesis develops the theory and method of the *practice perspective* through three studies.

First, a literature meta-review of previous tool reviews was carried out to identify potential perspectives. It was found that previously dominating perspectives are techno-centric, and at best user-centric, indicating that a relational view of practice is missing in existing research.

Second, ethnographic studies were conducted to explore ways of applying the practice perspective. Using the “interview to the double” technique with architectural practitioners in Nordic countries, it was found that previous activity-based models of the design process can guide tool development if extended to include the communicative purpose of design activities. Further, through observations in an architectural practice in Sweden, it was found that actors integrate sustainability in building design through a digitally mediated process of detecting and managing frictions. Digital tools both provide knowledge about the design situation (epistemic dimension), and structure how the design can be evaluated (normative dimension). The practice perspective highlights the normative dimension, by which the use of tools becomes relationally justified.

Third, to test the practice perspective in software development, it was applied during testing of the BSA tool prototype Heath in five Swedish architectural practices. The novel concept *practitioner experience* (PX) was formalised, initiating a heuristics formation process which expands the concept of user experience (UX) with attention to the relational context of digital interactions. It was found that conventional UX reflects usability, while PX emphasises usefulness.

The thesis contributes a practice perspective showing how digital BSA tools become useful to sustainable building design practitioners. The thesis proposes a tool characterisation framework, ethnographic methods, practice theories, and potential PX heuristics, making the practice perspective actionable during software development. The thesis can inform future development of BSA tools which are not only usable to design practitioners, but also useful in the complex relational context of sustainable building design practice.

Keywords

Life cycle assessment, Building performance analysis, Architectural design, Ethnography, Usability testing, User experience, Practice theory, Sustainable building

Praktikperspektiv på digitala analysverktyg för hållbar byggnadsdesign

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Institutionen för arkitektur och samhällsbyggnadsteknik

Chalmers tekniska högskola

Sammandrag

Digitala verktyg för hållbarhetsanalys kan hjälpa arkitekter att förstå och hantera byggnaders sociala och miljömässiga påverkan, men befintliga verktyg används sällan i designpraktiken. Medan tidigare forskning har fokuserat på att förbättra gränssnittens användbarhet för den enskilde praktikern utforskar denna avhandling istället hur verktygens nytthet kan förstås genom den relationella kontexten i designpraktiken. Avhandlingen utvecklar teorin och metoden för ett *praktikperspektiv* genom tre studier.

För det första kartlades möjliga perspektiv genom en meta-litteraturstudie av tidigare verktygsjämförelser. Studien fann att dominerande perspektiv under utvärdering av verktyg var teknocentriska eller användar-centriska, vilket indikerar att en relationell syn på designpraktiken saknats.

För det andra utforskades sätt att tillämpa ett praktikperspektiv genom en etnografisk studie innehållande intervjuer och observationer. Med hjälp av tekniken "dubbelgångarintervju" intervjuades arkitekturpraktiker från Norden, och därefter genomfördes etnografiska observationer på ett svenskt arkitektkontor. Tidigare aktivitetsbaserade modeller av designprocessen visade sig kunna vägleda verktygsutveckling genom att utökas med att beskriva aktiviteternas kommunikativa syfte. Det upptäcktes också att aktörerna integrerar hållbarhet i byggnadsdesign genom en digitalt förmedlad process av identifiering och hantering av friktioner. Digitala verktyg bidrar både med kunskap om designsituationen (epistemisk dimension), och genom att strukturera hur designen utvärderas (normativ dimension). Praktikperspektivet belyser den normativa dimensionen som motiverar verktygsanvändning.

För det tredje tillämpades praktikperspektivet inom mjukvaruutveckling vid testning av verktygsprototypen Heath på fem svenska arkitektkontor. Det nya konceptet *praktikerupplevelse* (*practitioner experience*, PX) formaliserades som en inledning på processen att ta fram en uppsättning tumregler som utökar konceptet användarupplevelse med hänsyn till den relationella kontexten för digitala interaktioner. Ett sedvanligt användarupplevelseperspektiv befanns beskriva användbarhet, medan praktikerupplevelseperspektivet fokuserar på nytthet.

Avhandlingens bidrag är ett praktikperspektiv som visar hur digitala verktyg för hållbarhetsanalys av byggnader blir nyttiga för praktiker. Den föreslår ett ramverk för utvärdering av verktyg, etnografiska metoder och teorier, och möjliga tumregler för PX som gör praktikperspektivet tillämpbart i mjukvaruutveckling. Avhandlingen kan stödja framtida utveckling av verktyg för hållbarhetsanalys som inte bara är användbara för designpraktiker, men som också är nyttiga i den komplexa relationella kontexten för hållbar byggnadsdesign.

Appended publications

- [Paper A] Säwén, T., Sasic Kalagasidis, A. & Hollberg, A. (2024). Critical Perspectives on Life Cycle Building Performance Assessment Tool Reviews. *Renewable and Sustainable Energy Reviews* 197, 114407.
- [Paper B1] Säwén, T., Sasic Kalagasidis, A. & Hollberg, A. (2026). Design as Communicative Activity: Implications for Building Sustainability Assessment Software. *Manuscript (under revision)*.
- [Paper B2] Säwén, T., Gao, X., Beemsterboer, S., Sasic Kalagasidis, A. & Hollberg, A. (2026). Networks of Friction at Interfaces for Sustainable Building Design. *Manuscript (submitted)*.
- [Paper C] Säwén, T., Malakhatka, E., Wiberg, M., Sasic Kalagasidis, A. & Hollberg, A. (2026). From User Experience to Practitioner Experience to Analyse the Usefulness of Building Sustainability Assessment Tools. *Manuscript (in review)*.

Table 1: Author contributions. TS: Toivo Säwén, ASK: Angela Sasic Kalagasidis, AH: Alexander Hollberg, XG: Xiaoxue Gao, SB: Sjouke Beemsterboer, EM: Elena Malakhatka, MW: Mikael Wiberg.

Paper	TS				ASK				AH				XG	SB	EM	MW
	A	B1	B2	C	A	B1	B2	C	A	B1	B2	C	B2	B2	C	C
Conceptualisation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Methodology	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Software				✓												
Formal analysis	✓	✓	✓	✓									✓		✓	
Investigation	✓	✓	✓	✓											✓	
Data Curation	✓	✓	✓	✓												
Original Draft	✓	✓	✓	✓									✓		✓	
Review & Editing	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Visualization	✓	✓	✓	✓												
Supervision					✓	✓	✓	✓	✓	✓	✓	✓				
Proj. Administration									✓	✓	✓	✓				
Funding Acquisition									✓	✓	✓	✓				

Other relevant publications and software

- [a] Säwén, T., Magnusson E., Sasic Kalagasidis, A. & Hollberg, A. (2022). Tool characterisation framework for parametric building LCA. *IOP Conference Series: Earth and Environmental Science*, 1078(1), 012090. <https://doi.org/10.1088/1755-1315/1078/1/012090>.
- [b] Säwén, T., Magnusson E., Sasic Kalagasidis, A. & Hollberg, A. (2022). A Characterisation Framework for Parametric Building Performance Simulation Tools. *E3S Web of Conferences* 362, 03004. <https://doi.org/10.1051/e3sconf/202236203004>.
- [c] Säwén, T. (2023). Early Stage Architectural Design Practice Perspectives on Life Cycle Building Performance Assessment. *Licentiate thesis, Chalmers University of Technology*, 2023:11. <https://research.chalmers.se/publication/538257>.
- [d] Säwén, T., Estève, P., Mjörnell, I., Galimshina, A., Habert, G. & Hollberg, A. (2024). Single Point of Contact: Density as a Mapping Parameter for Building Material Databases. *European Council on Computing in Construction 2024*, 253-276. <https://dx.doi.org/10.35490/EC3.2024.194>.
- [e] Säwén, T., Mjörnell, I., Sasis Kalagasidis, A. & Hollberg, A. (2025). The learning experience of Heath: a parametric life cycle building performance assessment tool. *IOP Conference Series: Earth and Environmental Science*, 1554. <https://www.dx.doi.org/10.1088/1755-1315/1554/1/012061>.
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- [g] Säwén, T., Wöhler, A., Berger-Vieweg, L., Tjäder, M., Hollberg, A. & Karlsson, I. (2025). Reduction Roadmaps: methods of determining limit-values for climate impact in construction. . *Phys.: Conf. Ser.*, 3140, 132020. www.dx.doi.org/10.1088/1742-6596/3140/13/132020.
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- [i] Säwén, T. (2026). Brimstone. *Software: version 1.8.0*. <https://github.com/sawenchalmers/brimstone>.
- [j] Säwén, T. (2026). Heath. *Software: version 0.9.3*. <https://github.com/sawenchalmers/heath>.

Acknowledgments

My research presented in this thesis has been funded by the Swedish Energy Agency, project number 51715-1, and by Formas, grant number 2021-01735. The research was conducted between March 2021 and August 2026. I would like to express my gratitude to numerous people who have inspired my work or, at times, offered a welcome distraction from it. A few shall be named here, but none shall be forgotten.

To my main supervisor Alex Hollberg who has trusted and encouraged me in following my curiosity, has taught me to cherish both successes and failures, and has always been available for an inspiring conversation to put my thoughts in order. To my co-supervisor Angela Sasic Kalagasidis, who has always offered sharp, encouraging feedback, and kept reminding me to mind my health foremost. To all colleagues at BT, SBE, and ACE - to Anna for being a friend in both highs and lows of the PhD life; to Xinyue for being the best deskmate I could ask for for five years, always cheerful and endlessly patient with my Chinese language skills; to Sanjay for being a role model for how to be an engaged, inspiring and supportive academic colleague; to Sjouke for the few lunch chats where I think my research advanced by months at a time; to Fredrik, Ali, Shuang, Xin, Quan, to Aida, Luca, Jieming, Emiline, to Maud, Leonardo, Jonathan, Yutaka, to Krystyna, Martine, to the ACE PhD council members, and all other colleagues for creating an open and welcoming research environment. To Elena, Xiaoxue, Mikael, Anton, and my other collaborators for engaging deeply with my work and revealing it in a new light. To all the students in ARK415 and ACE405, and my thesis students: Emil, Lina, Markus, Robin, Erik and Sebastian, for all the questions and all the inspiration. To my reference group for accelerating my work at the outset and anchoring it in practice, and to all the respondents in my empirical work for the unending insights into sustainable building design practice. To my examiner Holger Wallbaum and to Ingela for making the research possible, to Zoé and Tove for welcoming me at KTH, to my grading committee for the helpful feedback, and the opportunity to sharpen the thesis. To the Reduction Roadmap Sverige colleagues: Anna, Love, Maria, and Gustaf, for showing how research can lead to a real difference in society. To Birgitta and Kristina for the opportunities to write and put off writing at the ocean.

To Signe, Anneli, and Staffan, for being there for me, whether to take my mind off things or to listen and respond to my doubts and worries during this strange, wonderful time. Most of all, to Henny - you will always be my greatest inspiration.

Toivo Säwén
Svärdsjö, 2026-08-21

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Paper B2 - Networks of Friction at Interfaces for Sustainable Building Design

Paper C - From User Experience to Practitioner Experience to Analyse the Usefulness of Building Sustainability Assessment Tools

Acronyms

AI	Artificial Intelligence
ANT	Actor-Network-Theory
BIM	Building Information Modelling
BPA	Building Performance Analysis
BSA	Building Sustainability Assessment
CAD	Computer-Aided Design
HCI	Human-Computer Interaction
HTI	Human-Technology Interaction
LCA	Life Cycle Assessment
LCBPA	Life Cycle Building Performance Assessment
LLM	Large Language Models
PX	Practitioner Experience
TAM	Technology Acceptance Model
UCD	User-Centred Design
UX	User Experience

Part I

Integrative chapters

Chapter 1

Introduction

The ecological emergency (Ripple et al., 2019) calls for radical shifts to all human activities, including practices in the built environment. Buildings cause great environmental impacts, including but not limited to greenhouse gas emissions (Röck et al., 2020), irreversible resource use (Krausmann et al., 2018), and land appropriation (Zhao et al., 2015). The built environment also has great economic significance (Harvey, 1978), and a large influence on human wellbeing (Altomonte et al., 2020). The transition of construction practices toward activities within planetary boundaries (Rockström et al., 2009) thus requires a holistic view of sustainability, including ecological, social, and economic considerations (Hedenus et al., 2018). Architectural design is a key concern, as early decisions during a construction project greatly impact the final consequences in terms of sustainability (Østergård et al., 2017). Despite this, in current practice, quantitative assessment of building sustainability is often conducted only to confirm the performance once the design is completed, leaving little room for improvements guided by assessment results (Jusselme et al., 2020). In this thesis, I propose a practice perspective to better understand the gap between the benefits of applying building sustainability assessment tools, and their actual application in architectural design practice.

Building Sustainability Assessment (BSA) is the practice of predictively quantifying ecological, social, and economic impacts of a building during its conception (Bragança et al., 2010). BSA includes Life Cycle Assessment (LCA), applying a life cycle perspective to environmental impacts like global warming potential (Chau et al., 2015), and Building Performance Analysis (BPA), predicting the functional performance of a building and the wellbeing of its inhabitants by quantifying social impacts like thermal and visual comfort (de Wilde, 2019). The complexity of BSA methods, and the digitalisation of architectural design practices, have both contributed to BSA being digitally mediated through tools integrated in Computer-Aided Design (CAD) and Building Information Modelling (BIM) workflows (Hollberg et al., 2018).

The greatest opportunity for BSA tools to have a meaningful impact on the transition of construction practices toward operation within planetary boundaries is through integration in design process, when quantitative assessments can be utilised by architectural practitioners to select and develop well-performing design alternatives (Kanters and Horvat, 2012). Yet, despite great efforts to improve the *usability*

of digital tools originating in domains of technical expertise for use by architectural practitioners (Attia et al., 2024), surveys in current-day practice reveal that the great number of available tools sees little use (Mahmoud et al., 2020; Jusselme et al., 2020; Yu et al., 2022). It appears that improving usability is not enough to bridge the gap between tool development efforts and their uptake in practice. Another perspective is needed to be able to improve the *usefulness* of BSA tools to practitioners.

My hypothesis explored in this thesis is that it is through attention to the relational context - the *practice* - in which tools are intended to be integrated, that tool development efforts can focus on the gaps in terms of usefulness that prevent currently available tools from being widely implemented. Through the introduction of a *practice perspective* in the context of BSA tool development, I provide the theoretical and methodological foundations that can guide future tool development efforts focussing on usefulness in practice.

The practice perspective (Nicolini, 2012) is founded on the notion that sustainable building design is a contested, relational, and frictional practice (Kimbell, 2012). Building design is the process by which a perceived functional need or spatial valorisation opportunity translates to a realised intervention in the built environment through complex negotiations (Cuff, 1992) among property developers, architects, technical consultants, municipal decision-makers and urban dwellers - a process mediated by digital tools (Çıdık et al., 2017), regulatory instruments (Goulden et al., 2017), and certification schemes (Wallhagen and Glaumann, 2011). The negotiations play out during a wide range of design activities (Purup and Petersen, 2020a), during which the design space is explored and eventually settles into a final building design (Østergård et al., 2017) which is further detailed for construction. It is this relational context in which digital BSA tools need to embed to become useful to architectural practitioners.

To explore the practice perspective, I turn toward qualitative approaches and direct an ethnographic lens toward sustainable building design practices in Sweden. Sweden offers an interesting case because of the gap between high ambitions in terms of reduction of environmental impacts, and the limited rate of transition (Karlsson, 2024). I employ ethnographic approaches (Pink et al., 2010) because they provide an opportunity to understand complex, relational practices as they are being understood and navigated by practitioners (Kimbell, 2012).

My thesis responds to three key gaps in previous research supporting BSA tool development. Firstly, there has been no previous overview of how tools can be characterised in terms of their usability and usefulness for practitioners. Secondly, ethnographic approaches have not been applied to digital BSA tools in order to understand the processes by which they become useful to practitioners. Thirdly, no way has previously been proposed of making a practice perspective actionable in a BSA software development context. Through bridging these gaps, I contribute in my thesis with the theoretical and methodological underpinnings of the practice perspective on BSA tools. I synthesise the findings by outlining implications for the development of the next generation of BSA tools, guided by an understanding of how tools become useful to practitioners through embedding in the relational context of sustainable building design practice.

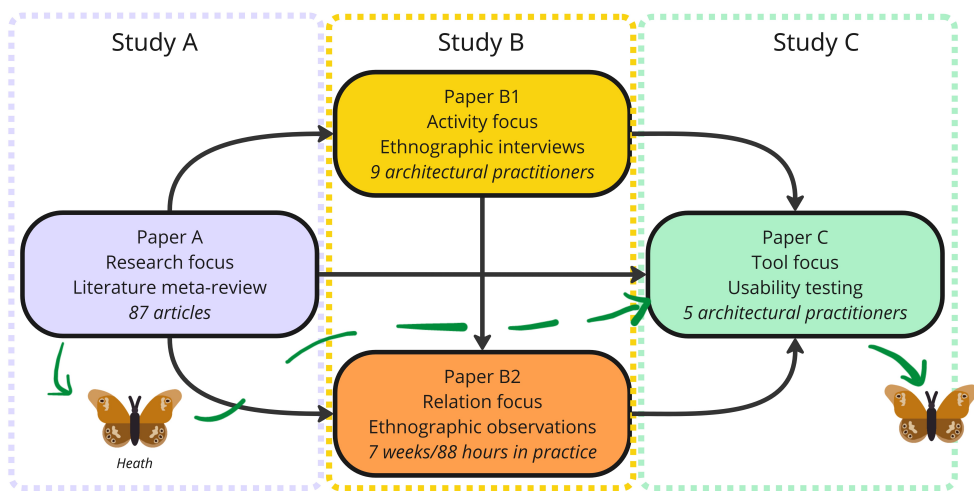


Figure 1.1: Overview of the three studies included in the thesis, including the paper, focus area, method, materials. Also indicates the parallel development of the BSA tool Heath (Säwén et al., 2025).

1.1 Aim and research questions

The aim of my thesis is to introduce a practice perspective supporting the development of digital Building Sustainability Assessment (BSA) tools intended for use in sustainable building design. I approach the aim through responding to the following research questions:

- Research Question A: What perspectives have previously been applied to digital tools for building sustainability assessment (BSA)?
- Research Question B: How can a practice perspective show how BSA tools become useful to architectural practitioners?
- Research Question C: How can a practice perspective be applied during BSA tool development?

1.2 Research design

The research I present in this thesis combines qualitative methods to apply a practice perspective to BSA integration in early architectural design stages in Sweden. An overview of the the three studies included in the thesis, including the relevant paper, focus area, method, material, is provided in Figure 1.1. Three studies are included: Study A, investigating the background through a literature meta-review (Paper A); Study B, developing new methods through ethnographic interviews (Paper B1) and observations in practice (Paper B2), and Study C, validating the proposed methods through software prototyping and usability testing (Paper C).

1.3 Structure of thesis

This thesis includes seven integrative chapters (the *kappa*) in Part I, which synthesises and contextualises the findings from the research, reflects on the research process, and indicates future research directions. Chapter 1 introduces the research topic and formulates the aims of the thesis. Chapter 2 presents the background and theories which guides the analysis. Chapter 3 presents the research design and methodology. Chapter 4 summarises and synthesises the key findings from the research. Chapter 5 critically examines the key findings in the light of the wider research context, and reflects on the research design. Chapter 6 presents the theoretical and methodological contributions, and outlines practical implications. Chapter 7 presents the main conclusions, and suggests future directions for tool development and research. Finally, the thesis includes the four appended papers in Part II.

Chapter 2

Background and theory

This chapter introduces views of sustainability in general and its application in building design, Building Sustainability Assessment (BSA) tools, usability and usefulness in software development, and the theoretical background of the practice perspective.

2.1 Sustainability

The original definition of sustainable development by the Brundtland commission defines a development which “meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland, 1987). The definition relies on many assumptions about the needs of present and future generations, which are difficult to make generally applicable. In this thesis, I adopt the view of Walsh et al. (2021) that sustainability is not a value-free given quality, but that it is a balance between ecological, social, and economic concerns (Hedénus et al., 2018) that is negotiated and constructed by the (human and non-human) actors engaged in social processes like building design. Important participants in the negotiations are human systems of governance like national and local legislation (Barjot and Malmqvist, 2024), as well as certification schemes (Wallhagen et al., 2013). Planetary systems also participate by offering material conditions and constraints for human activities (Latour, 2017). The constraints have been made visible through the concept of planetary boundaries (Rockström et al., 2009), representing anthropogenic impacts on planetary systems that are reversible - a condition to be able to claim that the needs of future generations can be met. Operations within the planetary boundaries represent human activities in a safe operating space (Petersen et al., 2022), ensuring the goal of meeting current needs without compromising the needs of future generations.

I thus define sustainability in a given social process as a negotiation in which all actors affected by the process are able to act to remain within the safe operating space. Beyond involved individuals and organisations, the participating actors include human systems of governance acting to balance social and economic concerns, as well as planetary systems acting to ensure that environmental impacts are reversible. To translate this to sustainable building design, the next section describes building design practice, especially in the Swedish context relevant to my thesis.

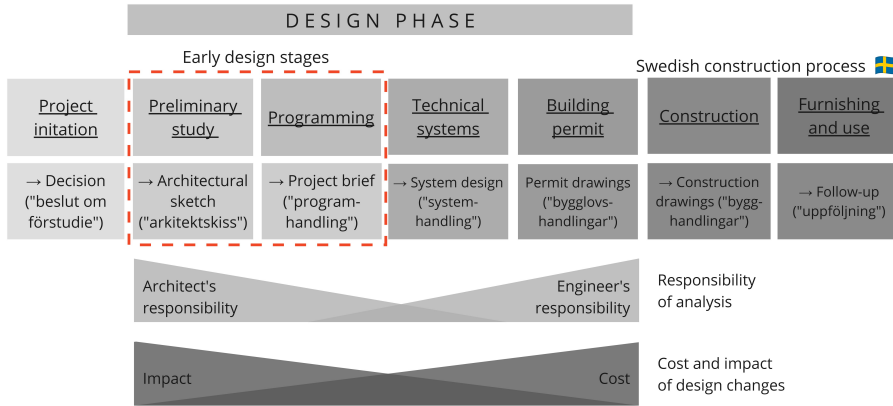


Figure 2.1: Overview of design stages as defined in Sweden (Hansson et al., 2015). Further, schematically shows changes to the involvement of architects and engineers during the process (Morbitzer, 2003), and to cost and impact of design improvements (Paulson, 1976).

2.2 Building design

Building design is the process by which a perceived functional need, or opportunity for realisation of spatial value in the built environment (Harvey, 1978), is translated into a realised physical intervention (Weisman, 1994). Commonly, this means a property developer or client employs an architect to develop a building concept for a specific property. As shown in Figure 2.1, in the Swedish context relevant to my thesis, the design process can conventionally be divided into three phases following preliminary studies and project initiation by the client (Hansson et al., 2015): first, a schematic phase or *early design stage* where architects develop initial concepts; second, a detailed phase where the concept is developed and engineers join the process to design technical systems; and third, a construction phase where drawings are being submitted for legislative approval, and prepared to be used in construction.

2.2.1 Integrated design process

In the early stages of a design project, changes are less costly and have greater impact on performance outcomes, as less details have settled (Hollberg, 2016). This means changes to the design and selection of design alternatives can more easily be made in response to predictive BSA results. A commonly proposed way of achieving this is the *integrated design process* (Kanters and Horvat, 2012), during which engineers with domain-specific technical expertise are involved even in early design stages. The concept is that sustainable building design is enabled through early consideration of technical aspects, improving the chances of achieving a desired level of building sustainability as the design is developed and finalised. As shown by Negen-dahl (2015), this collaboration can happen in a variety of setups in practice, ranging from the engineer being available for the architect upon request, to being an fully integrated member of the design team and evaluating design alternatives as they are being developed by the architects. However, despite the promise of such possible arrangements, the prevailing distribution of responsibilities in current Swedish

building design practice is the one shown in Figure 2.1, where the architect is the principal designer in early design stages, and engineers enter later to confirm the performance of the final design alternative and detail technical systems (Morbiter, 2003; Kanter and Horvat, 2012; Hansson et al., 2015).

It has been commonly argued that it is during the early, schematic, conceptual phase that architectural practitioners can create the greatest improvement in terms of sustainability of the building design (Østergård et al., 2016; Meex et al., 2018). Based on this argument, my thesis focusses on the integration of BSA tools in early design stages, where the architect is normally the main actor developing the design proposal. This implies that BSA tools need to be adapted for the needs within the sustainable building design practice of architects. As Bleil de Souza (2012) shows, architects and engineers approach design in different ways, which means the adaptation of BSA tools must consider contrasting design paradigms.

2.2.2 Models of the design process

Great efforts have been expended to analyse designerly ways of knowing (Cross, 1982), to understand building design and model the design process (Dorst and Dijkhuis, 1995), either as rational problem-solving activity (Simon, 1969), or as reflection-in-action (Schön, 1983). This work has highlighted the challenge of introducing BSA in early design stages which stems from conflicting problem-solving regimes (Bleil de Souza, 2012): engineers aim to simplify and isolate problems with known bounds, permitting optimisation, whereas architects embrace complexity and the wickedness of the design situation, and thus aim for a state of *satisficing*, where an acceptable solution is identified among a wide range of possible alternatives (Schön, 1983).

Lawson (2006) shows that the navigation from problem to solution through a range of design activities is rarely linear, but composed of a constant interplay of analysis, synthesis, and evaluation. Empirical studies through observations and interviews confirm this view of the complexity and non-linearity of the design process (Goldschmidt and Rodgers, 2013), and propose that a fine-grained understanding of design activities guiding tool development could help overcome the challenge of adapting BSA tools for use in early design stages (Purup and Petersen, 2020a).

This attention to designerly ways of knowing has been challenged in more recent work, which understands design work as contested, relational, and frictional (Kimbell, 2012). In this context, BSA tools enter the design process not as indifferent sources of information helping solve problems with known bounds, but as active participants in the design process which prompt conversations that allow knowledge about the emerging design to be shared among various actors (Luck, 2007; Ewenstein and Whyte, 2009). This view of the design process regards it not as problem-solving within known bounds, but the issue-raising through exploring what those bounds could and should be (de Marinis and Rowan, 2025).

The negotiations taking place to determine what is sustainable building design are mediated in practice by a range of tools, including digital tools predictively quantifying environmental and social impacts, and certification schemes and legislation benchmarking the outputs of the quantitative assessments against what is normatively agreed to be sustainable. The application of quantitative tools to predict impacts outlines the practice of building sustainability assessment, introduced next.

2.3 Building sustainability assessment

*Building sustainability assessment*¹ (BSA) is the practice of quantifying the sustainability of a building through metrics reflecting ecological, social, and economic factors (Bragança et al., 2010). The assessment can be carried out for the building-as-built, which uses detailed knowledge about the construction materials used, real energy consumption, and measured thermal and visual comfort. However, of greater interest for sustainable building design is *predictive* BSA, as it permits reacting to the assessment results during the design process, and changing the design in response (Basbagill et al., 2013). The earlier the assessment is conducted, the greater is the opportunity to make design changes in response, although the lack of information can make the assessment challenging (Meex et al., 2018).

2.3.1 Building sustainability assessment approaches

Widely applied BSA approaches include Life Cycle Assessment (LCA), quantifying the environmental impacts of a product such as a building with a life cycle perspective (Chau et al., 2015), and Building Performance Analysis (BPA), quantifying the functional performance of a building including environmental and economic factors like energy usage, and social factors like wellbeing, and visual and thermal comfort (de Wilde, 2019). These methods are formalised in Sweden through inclusion in national legislation (Barjot and Malmqvist, 2024), through municipal building permit processes (Hansson et al., 2015), through environmental certification schemes (Wallhagen et al., 2013), and through the design brief (Ryd, 2004) and formalised sustainability ambitions of project clients and other stakeholders (Gluch, 2009).

When applied during building design, BSA methods require transferring the building-as-designed into a digital assessment model, which includes geometric and semantic information. The assessment model can then be used as input for computational simulation and calculation engines which output the relevant metrics and allow the predictive quantitative assessment.

The assessment methods in domains of technical expertise beyond that of the architect, including environmental science and building physics. This has traditionally caused the emphasis in tool development to be on precision and technical rigour, rather than usability, as the users are expected to navigate complex interfaces and have a deep understanding of the analytical foundation of the assessment. In previous research, the limited usability of early BSA tools has been considered a barrier to tool adoption among architectural practitioners, causing them to be relegated to confirming building sustainability upon design completion (Meex et al., 2018) and thus having limited impact on the design (Clarke and Hensen, 2015). However, despite great efforts during the past decade to improve the usability of BSA tools (Attia et al., 2024), they remain underutilised among architectural practitioners (Mahmoud et al., 2020; Jusselme et al., 2020; Yu et al., 2022). In this thesis, I hypothesise that the great efforts to improve *usability* have overshadowed a consideration of the *usefulness* of BSA tools. To understand the difference, I will first provide a view of what a digital BSA tool can look like.

¹In my Licentiate thesis (Såwén, 2023), and in Paper A, the term Life Cycle Building Performance Assessment (LCBPA) was used to refer to quantitative sustainability assessment in the design process. In this thesis, I consistently use the term Building Sustainability Assessment (BSA) to refer to such practices.

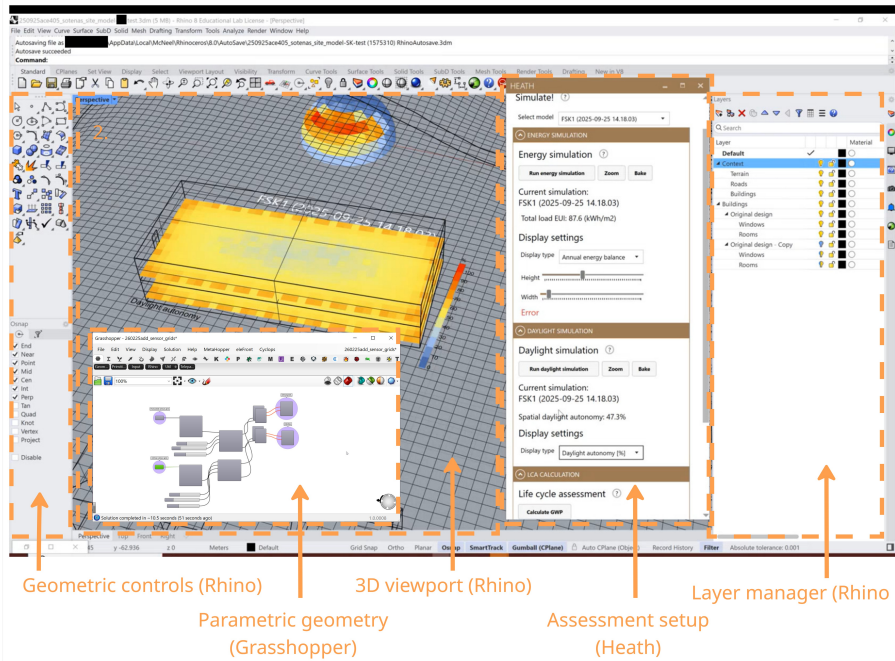


Figure 2.2: Example interface of the digital BSA tool Heath, as captured during the usability testing session carried out in Study C. Edited, used with permission from the respondent.

2.3.2 Digital building sustainability assessment tools

Because architectural design models need to be adapted for quantitative assessment, digital BSA tools are commonly integrated in design tools like CAD (e.g., AutoCAD or Rhino) or BIM (e.g., Revit or Archicad), or implemented as standalone software with interoperability with design software (Säwén et al., 2022a; Säwén et al., 2022b). A widespread method of adding semantic information (like material properties or space occupancy, relevant both for thermal analysis and life cycle assessment) to a purely geometric model is through parametric modelling (Hollberg, 2016). In general, a parametric model is one where geometric and semantic information is defined through numeric and textual inputs in the graphical user interface, and can then be varied parametrically based on potential configurations relevant for the design case. In two conference articles, I provide an overview of available parametric tools for LCA (Säwén et al., 2022b) and BPA (Säwén et al., 2022a).

Figure 2.2 shows an example digital BSA tool interface: the Heath tool which I have developed in parallel with the ongoing research, and implemented using Grasshopper, HumanUI, and Python (Säwén et al., 2025). The screenshot has been captured during usability testing session carried out in Study C of this thesis. The figure shows the host Rhino interface which offers geometric modelling capabilities (left), the viewport (top, middle) which shows both the input geometry and assessment results (in this case, a daylight autonomy simulation), and a layer manager (right) which organises the different types of geometry in the model. Docked in the viewport is the Grasshopper interface, where geometry is defined parametrically.

The figure also shows the Heath interface, where parametric inputs can be entered to change simulation settings and assumptions for, among other things, material properties and space usage.

The example interface of Heath shown here has been developed based on a perspective of improved usability, following user-centred design principles. However, in this thesis, I propose instead emphasising usefulness through a practice perspective. Next, I will show the distinction between usability and usefulness, the origins of these terms in human-computer interaction research, and their relevance for BSA tool development,

2.4 Usability and usefulness

Usability and usefulness are both aspects of the Technology Acceptance Model (TAM), which is a systematic way of analysing how technologies become accepted and taken up in organisations (Davis, 1986).

The importance of considering a user perspective is a key aspect of Human-Computer Interaction (HCI) research (Malakhatka and Wiberg, 2025), an insight which has motivated the attention to User-Centred Design (UCD) as a dominating principle in recent decades of software development (Wallach and Scholz, 2012). UCD emphasises the *usability* of technology (Gould and Lewis, 1985), which is defined as the quality of interactions between humans and technology, or put more simply, the ability of a user to carry out certain desired actions. Usability evaluation is formalised during software design through the heuristic evaluation method (Nielsen, 1996). Methods of capturing the user perspective include user stories (Lucassen et al., 2016) and user personas (Johansson and Messeter, 2005).

While the UCD-guided software development approach pays close attention to the interactions between the individual user and the digital interface, it makes the assumption that the digital interaction is useful to the practitioner. In TAM terms, this means usability overshadows the *usefulness* of technology (MacDonald and Atwood, 2014). TAM defines perceived usefulness as the “belief that the use of a technology would improve job performance” (Davis, 1986). I instead apply a practice perspective by defining usefulness as the contextual factors which cause certain actions to be perceived as meaningful and justified. While UCD is effective to help understand the usability of digital systems, analysis of usefulness according to TAM is limited to asking practitioners about how they perceive it, which disregards how it is being constructed through the interactions among the numerous actors in the sustainable design process (Nocera et al., 2007).

This thesis investigates whether the concept of usefulness of BSA tools can be nuanced by emphasising how tools become useful through embedding in the relational context of sustainable building design practice. The attention to the relational context of practice has been a recent shift in how design process can be modelled - developments providing the theoretical foundations for my research.

2.5 Theoretical framework - the practice perspective

The practice perspective acknowledges human activities as always materially and discursively situated (Nicolini, 2009), which is true also for design (Kimbell, 2012). The practice perspective shows how technology use emerges through the situated activities of practitioners (Orlikowski, 2000). It further foregrounds how multiple

actors, both human and non-human (Latour, 2007), coincide to produce practices together (Kimbell, 2012). The practice perspective, which often relies methodologically on ethnographic methods (Nicolini, 2012), is explored in my thesis to understand the negotiations during which the actors in the design process, mediated by digital BSA tools, collaboratively define how to evaluate sustainable building design (Dossick et al., 2019). As theoretical foundations (Nicolini, 2012), the practice perspective proposed here draws upon two important frameworks: activity theory (Engeström, 2001), and actor-network-theory (Latour, 2007).

Activity theory captures the relational context in which BSA tools become useful in sustainable building design practice by using the human activity as a unit of analysis. The activity is described in terms of its *subject* (the user) engaging in the activity, its *object* (the task) of the activity, and the *tool* (the digital BSA interface) by which it is carried out, and further through the *community* (the discursive context) and the *rules* (the normative system) that causes it to be perceived as justified and necessary (Engeström, 2001).

Actor-network-theory (ANT) offers several conceptual instruments which support the practice perspective. The most important is the notion of *actor*, which in ANT is understood as *any thing* which modifies the state of affairs (Latour, 2007). “Any thing” is to be taken literally, actors range from human to non-human who assemble to constitute any social process, like the one of design practice (Fallan, 2008). In the context of the built environment, this includes the participants in the design process (Cuff, 1992), the human dwellers of the built environment (Fallan, 2008), plants and animals of the biotic environment (Ernstson, 2013), local abiotic entities like streets, buildings, and infrastructure (Yaneva, 2008), global abiotic entities like the planetary crust and atmosphere (Latour, 2017), and the virtual entities like digital, analogue, and legislative tools which influence the design, for instance software (Harty, 2010) and drawings (Lindgren, 2024), regulations (Kitchen, 2000), and certification schemes (Goulden et al., 2017). The ANT perspective on building design treats it as a process of stabilisation of certain networks representing different interests (Schweber and Green, 2026). It is through negotiations and frictions (Rose, 2016) among actors that the building stabilises as an epistemic object (Ewenstein and Whyte, 2009), which can be realised as an intervention in the built environment.

Through this wide perspective of what things are perceived to *act* in the design process, digital BSA tools can be understood through their role in *mediating* sustainable building design (Latour, 2007). Through *translating* sustainability into specific metrics, digital tools act to make benchmarking and design alternative comparison possible (Østergård et al., 2016), but simultaneously to simplify complex topics (Çıdık et al., 2017), and potentially silence alternative perspectives (Goulden et al., 2017). I apply the terms *networks*, *interfaces*, and *frictions*, as defined by Rose (2016) to understand this process. Digital tools participate as interfaces at which the formation of networks among actors occurs. The negotiations by which sustainability in the design process is defined causes the networks to experience frictions: moments in the process where cultural meaning, such as a building-during-design, “pauses and materialises in specific places with specific people”, and is “encountered, interpreted, ignored, lost, liked, resisted and deleted”, reflecting the fact that “interfaces don’t always work smoothly” (Rose, 2016). In this way, I consider design processes as the formation of networks of friction, mediated by digital interfaces: BSA tools.

I further acknowledge that when BSA tools act in building design, they do not only descriptions provide scientific explanations of physical or social processes, but also help define what is considered a value such as “sustainable building” (Schneider et al., 2019). In my thesis, I refer to this as acting in the *epistemic dimension* (describing and explaining processes) and in the *normative dimension* (ascribing value to processes).

It should be noted that although my findings are intended to be useful in software development practice, I do not directly study *software development practitioners*, beyond observing examples of computational design integration in architectural teams. The practice perspective I propose thus refers to a way for software developers to gain an understanding of the usefulness of BSA tools through capturing the relational context of software integration.

Chapter 3

Methodology

This chapter presents an overview and alignment of the applied methods, whereas details regarding the method application is available in the appended papers.

The research presented in this thesis is interdisciplinary: it deals with the challenge of translating assessment methods, developed in fields of life cycle assessment and building performance analysis, for use in architectural design, by examining the usefulness of digital assessment tools in sustainable building design practice, through a theoretical perspective largely retrieved from social sciences. The research approach is inductive in working mostly with ethnographic methods, constructing theoretical generalisations from particular observations in practice.

The research is interpretivist as it relies on interpreting the meanings (such as “sustainable building design”) ascribed to experiences by actors in practice. It is also social constructionist in understanding these meanings as constructed through social processes and interactions (Walsh et al., 2021), with a focus on how practices are constituted through human actions and interpretations. By emphasising the relational, networked nature of tool integration in design processes, and acknowledging the importance of non-human *actors* in these networks, the research adopts a material-semiotic worldview (Latour, 2007). This view highlights how practices emerge through networks of relations that are simultaneously material (things, technologies, etc.), and semiotic (meanings, discourses, representations, etc.).

3.1 Methods and materials

The research I present in this thesis combines qualitative methods to inductively develop the practice perspective for digital BSA tools. The empirical data collection methods I have applied to develop the practice perspective include literature meta-review (Study A), ethnographic interview (Study B1) and observation (Study B2), and usability testing of a software prototype (Study C). An overview of the data collection methods and materials is presented in Table 3.1.

The cases investigated have focussed on the integration of BSA in architectural design practice in the Nordic countries, with emphasis on Sweden. This case selection was made partly out of practicality as the research is conducted in Sweden, but is relevant in the general context of sustainable building design because of the great gap between sustainability ambitions and actual implementation in Swedish

Table 3.1: Overview of method and materials

Research question	Study	Method	Materials
What perspectives have previously been applied to digital tools for building sustainability assessment (BSA)?	A	Literature meta-review (Post et al., 2020)	88 previous BSA tool reviews from scientific literature published 1998-2023
How can a practice perspective show how BSA tools become useful to architectural practitioners?	B1	Interview to the double (Nicolini, 2009)	Interviews carried out 2022-2023 with 9 architectural practitioners in Sweden and Norway
	B2	Participatory observation (Pink et al., 2010)	Communicative activities during two design projects in a Swedish architectural practice, observed for 88 hours during 8 weeks in May-June 2024
How can a practice perspective be applied during BSA tool development?	C	Software prototyping, usability testing (Wallach and Scholz, 2012)	Tool prototype of Heath developed 2023-2025, 5 testing sessions with architectural practitioners in Swedish architectural practice from June-September 2025

construction practices (Karlsson, 2024). The materials collected represents a wide perspective on design integration of BSA, from the views of BSA tool developers, largely with an engineering background, collected from research literature, to interviews with architectural practitioners applying BSA in practice, to observations of client-architect interactions, and finally the perspective of architectural practitioners during interactions with a BSA tool prototype.

After data collection, I applied variations of thematic analysis to explore the collected qualitative data. The thematic analysis procedure in each study follows the six steps shown in Figure 3.1 (Braun and Clarke, 2006), with adaptations in each study based on the specific research objective. While the analysis was generally inductive and grounded in the empirical data during generation of initial codes, previous research often inspired the categorisation and grouping in themes: Attia et al. (2012) in Study A, Purup and Petersen (2020a) in Study B1, and Nielsen (1996) in Study C.

Figure 3.2 shows a more detailed overview of the participants in the ethnographic studies (Study B1 and B2) and usability testing (Study C). Representatives from fifteen organisations are included, one of which is represented in each of the three studies; and two individuals participated in two studies each. The sampling strategy can be considered convenience sampling (Golzar et al., 2022), as the respondents were recruited from the professional network of myself and my research team.

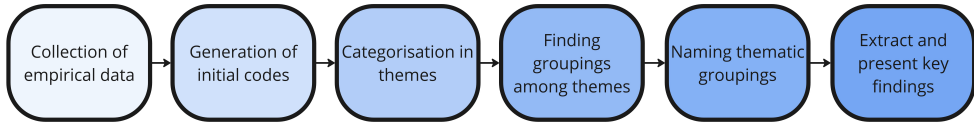


Figure 3.1: Overview of thematic analysis steps applied in each study.

3.1.1 Literature meta-review (Study A)

The research question in the literature meta-review in Study A was “What perspectives have previously been applied to digital tools for building sustainability assessment (BSA)?”. To this end, tool reviews in the BSA research field, including tools for life cycle assessment, energy simulation, daylight simulation, and other BPA approaches, were collected from available literature published between 1998-2023. The meta-review approach was chosen as it allows identifying prevailing research streams and methodological approaches in a research field (Post et al., 2020), and because it is useful to integrate the findings of a large collection of studies and compare methodologies (Sarrami-Foroushani et al., 2015). I studied tool reviews as they provide a view on what the research community interested in developing tools has deemed to be important characterisation criteria guiding future developments. The literature was collected partly through semi-systematic searches in Scopus database using the following keywords:

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(TITLE-ABS-KEY((tool* OR software*) AND (review* OR
evaluation*))) AND (TITLE-ABS-KEY(architect* OR design*
OR energy OR daylight OR "building performance" OR
"life cycle assessment" OR lca OR environment* OR
"thermal comfort"))
  
```

Once an initial set of articles had been identified, additional material was collected through snowballing. The final sample of materials was a set of 87 relevant tool reviews which were included in the systematic conceptual framework analysis based on applying systematic approaches to characterise BSA tools.

Thematic analysis was applied to the set of documents to identify previously applied characterisation criteria in a first round of coding. Once a tentative set of criteria had been defined, the second round of coding involved categorisation of the criteria, and organisation into a conceptual framework informed by previous work (Attia et al., 2012). The final step of the analysis was applying a critical perspective to previous approaches, in order to identify potential gaps and future directions.

3.1.2 Ethnographic interview (Study B1)

I applied ethnographic methods in Study B in response to the research question “How can a practice perspective show how BSA tools become useful to architectural practitioners?”. The methods included interviews (Study B1) and observations (Study B2), developing a triangulated view of the state of BSA integration in current early-stage architectural design practice in Nordic countries, especially Sweden.

For the interviews in Study B1, nine architectural practitioners active in different practices in Sweden and Norway were recruited. The ethnographic interview method applied is referred to as the “interview to the double” (Nicolini, 2009). Using

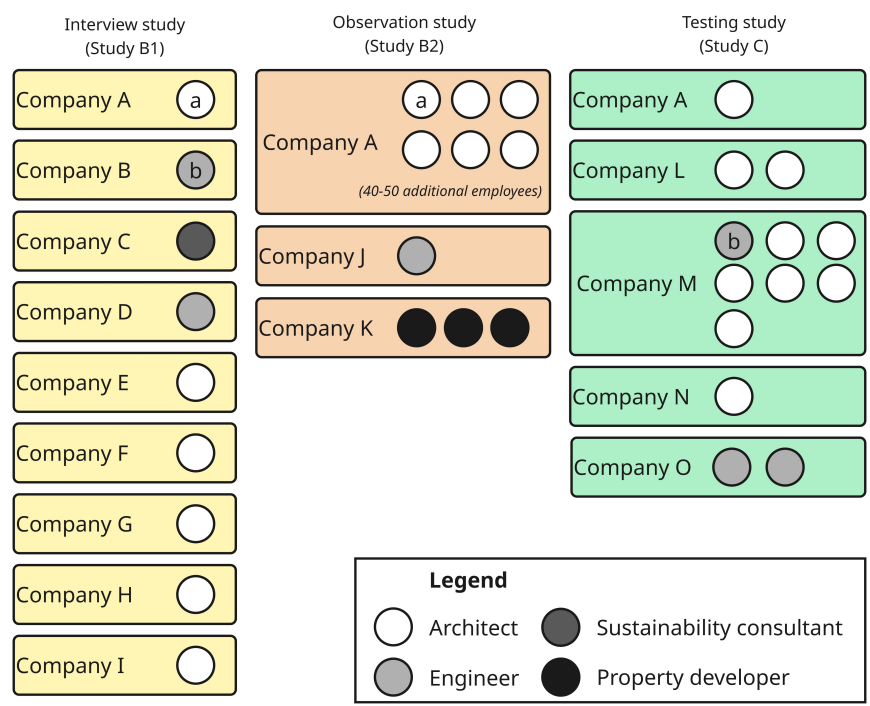


Figure 3.2: Overview of respondents and informants in the ethnographic studies and usability testing. Each circle represents one individual respondent. One company (Company A) is included in all three studies. Two respondents (a and b) participated in two studies each.

this semi-structured interview method, the respondent is asked to imagine that the interviewer is a body double who will assume their work tasks for the next workday. The respondent is then asked to provide instructions for these tasks detailed enough that the imagined body double could carry them out without being discovered. The interviews, conducted during 2022-2023, were recorded, and manually transcribed verbatim.

The thematic analysis of the interviews focussed on identifying the activities of the architectural practitioners, related to BSA and beyond. In the first step of coding, the activities were described in the words of the respondents. Then, once a set of activities had been identified, similar activities were grouped and categorised, the categorisation partially informed by previous work by Purup and Petersen (2020a). Finally, the presence or absence of BSA tools in the specific design activities was critically examined to identify potential gaps and opportunities in terms of digital mediation of design activities.

3.1.3 Participatory observation (Study B2)

I carried out the ethnographic observations in Study B2 over a continuous eight week period in May-June 2024. I documented the communicative activities in two early-stage design projects in a Swedish architectural practice with 50-60 employees, through participatory observation (Brett et al., 2022). The observations were

participatory in the sense that I offered BSA inputs to the design team during communicative activities. In the two design projects, I attended communicative activities whenever possible. In total, fifteen communicative activities were documented. This included formal physical and digital meetings with clients and technical consultants (Le Dantec, 2010), and formal and informal physical meetings among the architects (Boudeau, 2013). During the activities, notes were taken digitally, and summarised each day based on tentative categories of “sayings”, “doings”, and “relatings” (Kemmis et al., 2013).

The observation notes were iteratively coded through thematic discourse analysis. In the first coding step I identified actors mentioned as relevant in the discussions among the practitioners. Actors are understood here in the actor-network-theory sense including humans and non-human entities acting in the design process (Latour, 2007). Once a set of actors had been identified in the material, in the second coding step I analysed the interactions and interrelations between them, yielding a set of actor interaction chains. This permitted an overview of the network of actors. In the final coding step, recurring patterns in these interactions were identified, referred to as patterns of mediation. These patterns reveal recurring ways by which digital systems and other actors mediate actions that co-produce the design process, eventually enabling physical interventions in the built environment.

3.1.4 Software prototyping and usability testing (Study C)

In Study C, I responded to the research question “How can a practice perspective be applied during BSA tool development?” through usability testing of a software prototype with architectural practitioners from five different offices in Sweden. Two versions of the software prototype Heath (Säwén et al., 2025), developed in the educational context at Chalmers based on the previous BeDOT tool (Fantin Do Amaral Silva and Bergel Gómez, 2018), was used in testing sessions. Data was collected through a preparatory questionnaire capturing the participants’ background and expectations, through observation during hands-on testing sessions, and through follow-up interviews with the participants based on User Experience (UX) heuristics (Nielsen, 1996). The testing sessions and interviews were recorded and manually transcribed verbatim.

The aim of the analysis was to compare the application of a conventional user perspective (Wallach and Scholz, 2012) to the novel practice perspective. I applied thematic analysis inductively to the transcribed notes and interview responses during the recorded testing sessions, to identify software requirements. In the first coding step, the observation and interview responses were reformulated as user stories in the format “as a <user>, I want <goal>, so that <reason>” (Cohn, 2004). Second, the stories were categorised into broader thematic categories. Third, the categories were characterised based on whether they have relevance for the individual user, or pertain to the relational embedding of the interface in the wider practice. Finally, the categories relevant in the wider relational context were reformulated to provide the starting point for a heuristics formation process, indicating a transition from individual-oriented User Experience (UX) to relation-oriented practitioner experience Practitioner Experience (PX).

3.2 Ethical considerations

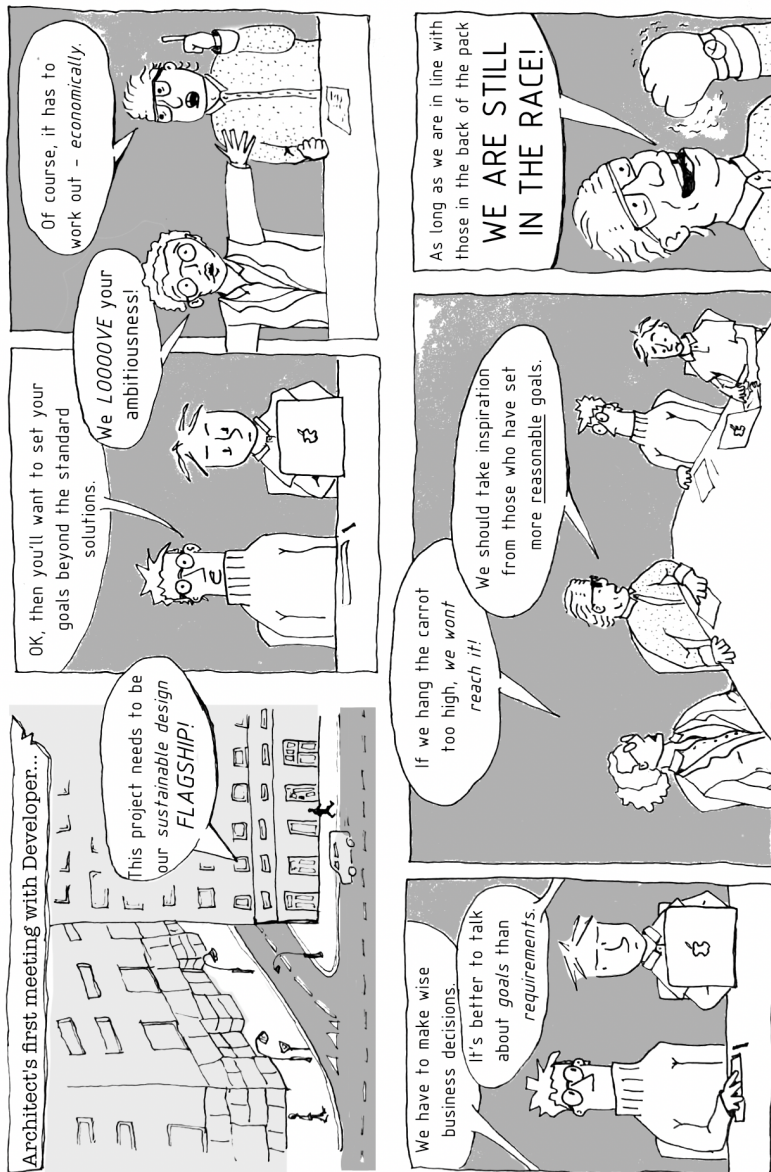
The research presented in this thesis was not submitted for ethical review since the methods and materials were not within the boundaries of research requiring ethical review in Sweden (Swedish Ethical Review Authority, 2021). The main ethical concern with the research is that it deals with human participants, including interview and observation participants. All participants were informed about my identity as a researcher, the purpose of the research, and the guiding research questions. As far as practically possible consent was acquired from each individual, and secondarily on an organisational level from participating organisations. Participants were permitted to review manuscripts before submission. Demographic information was self-reported using questionnaires and if not self-reported, it was left out of the analysis. The collected raw data was anonymised and available only to the research team.

Another consideration is the environmental and social impacts of the research. The framing of the project is guided by the recognition of the responsibility for the research community to contribute to resolving the ongoing climate emergency, and to guide practice by providing approaches that contribute to a socially just transition to human activities within the safe operating space. It is expected that the negative environmental impacts of the work are limited, and that the findings, if implemented in practice, can contribute to reduced negative impacts of design activities, offsetting the impacts caused by the research process.

3.2.1 Use of large language models (LLM)

During the course of the PhD project, quick developments have occurred in the field of generative Artificial Intelligence (AI), through the emergence of publicly available Large Language Models (LLM). While the relevance of these tools in a research context is contested (Abdelhafiz et al., 2024), I have explored their utility as part of my research practice. I have identified and tested five different use cases, briefly discussed here in relation to potential ethical considerations for my research, and future work.

- **Improving wording** has been limited to individual word choices, in order to preserve stylistic consistency and avoid potential copyright infringements.
- **Writing code** is yet immature in requiring manual tweaks to work, but has supported the research work through simple scripts which can be tested easily.
- **Improving understanding** can be achieved through summarising concepts available in literature, but any LLM outputs have been carefully cross-checked against referenced material.
- **Literature review** through services like Elicit and Google Scholar has low precision, yet has offered an alternative avenue to traditional keyword searches by identifying different material.
- **Analysis of qualitative data** is attractive to analyse great amounts of textual data (Hayes, 2025). To avoid compromising respondent confidentiality and methodological integrity, the use has been limited to secondary data and comparison with manual approaches, using LLMs to validate interpretations and identify potential gaps or alternative categorisations. Their inability to provide traceable analytical reasoning limits their usefulness as a sole method of qualitative analysis.



Vignette 1: This vignette, and the two following, show an artistic interpretation of the empirical observations in Study B2. The narrative shows the discrepancy between high ambitions, and actual efforts to transition practice. ©Anton Arnby, 2026, used with permission.

Chapter 4

Findings

In this chapter, I summarise and synthesise the findings from the included studies. Detailed results are presented in each of the four appended papers, and initial findings have previously been reported in my licentiate thesis (Säwén, 2023).

4.1 Tool perspectives in literature (Study A)

During preliminary literature reviews supporting a mapping of available BSA tools, I hypothesised that there was a lack of consistent tool review methodologies (Säwén et al., 2022a; Säwén et al., 2022b). The purpose of Study A was to provide a comprehensive view of literature reviewing BSA tools (Säwén et al., 2024).

I confirmed the hypothesis that there was no consistent, systematic tool characterisation methodology provided in the tool review literature. Instead, tool reviews have generally been carried out based on methodologies developed in each study, making direct comparison difficult. By systematically detecting and categorising characterisation criteria applied in previous reviews, I developed a conceptual framework, supporting a comprehensive, systematic tool review methodology. As shown in Figure 4.1, five categories are included in the conceptual framework: 1) analysis capabilities, 2) information management, 3) user interface, 4) design support, and 5) practical integration. I found that the three former categories, focussing on technological advancement and user interactions, are the main emphasis in previous tool reviews. This indicates a gap in terms of the two latter categories, covering the experience of the design practitioner in the context of design practice. This gap was further analysed from three critical perspectives: a user perspective, a design process perspective, and a design practice perspective.

From a tool user perspective, I found that the description of the intended user from whose perspective the tool reviews are carried out is often vague or entirely missing. User aspects are instead mostly limited to the visual appearance of the interface, emphasising ease of data entry and navigation. This indicates a need for clearer definition of the practitioner as intended user.

From a design process perspective, I found that tools are mostly evaluated based on their ability to support specific problem-solving activities, with a limited view to how those activities fit into a wider context. This indicates that tool reviews need

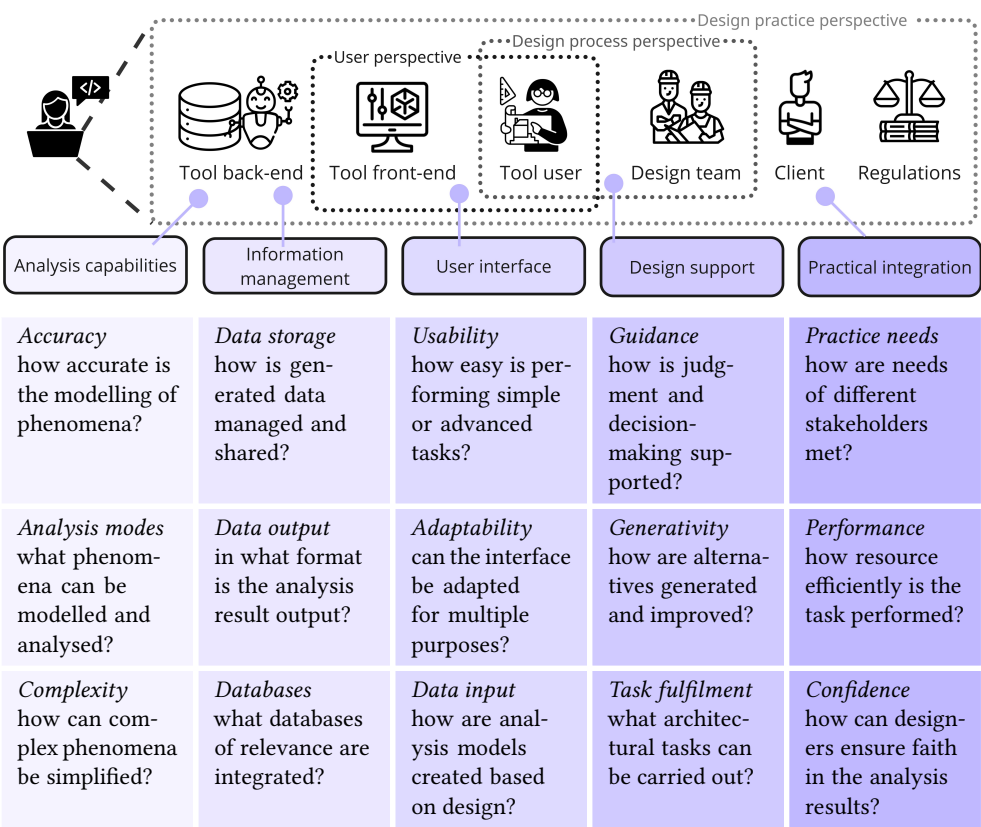


Figure 4.1: Perspectives applied in the literature meta-review, and links to the developed characterisation criteria.

to take consider the work necessary to create the input for the assessment, and how the assessment outputs are utilised in communication with other actors.

From a design practice perspective, I found that tools are mostly evaluated based on how use in one individual design project. This indicates that further work is needed to see how learnings from one project is transferred to the next, and what are practical barriers to the uptake of an assessment tool at an organisational level.

To summarise these findings, the view of design practice and design practitioners has been limited in the state-of-the-art of BSA tool research. The following studies aimed to provide the methodological and theoretical foundations that investigate practice (Study B), and integrate the practice perspective in software development (Study C).

4.2 A proposed practice perspective (Study B)

Based on the identified lack of practice perspectives in tool evaluations, in Study B I explored ethnographic methods of providing an understanding of sustainable building design practice, including interviews (Säwén et al., 2026c), and observations (Säwén et al., 2026a).

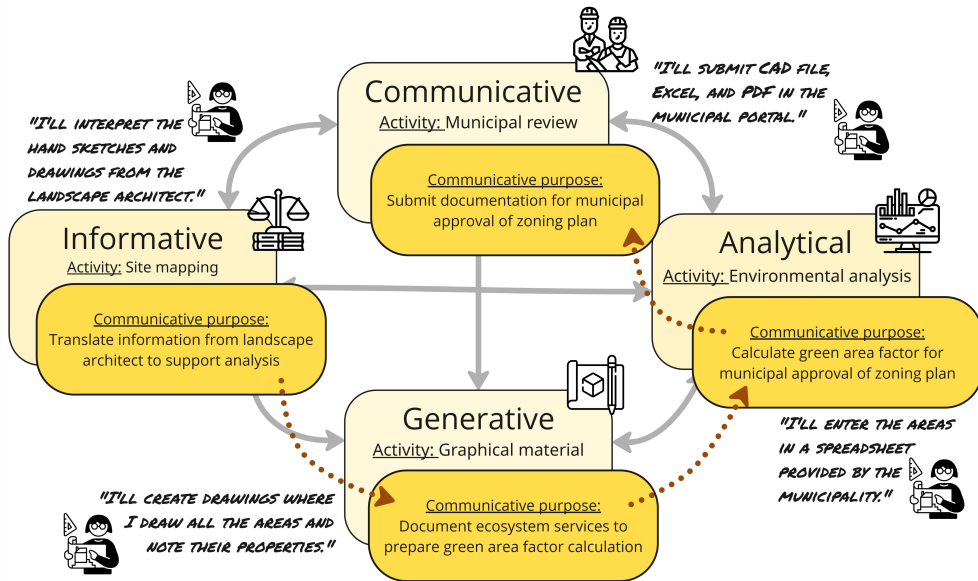


Figure 4.2: Activity-based model of the design process, revealing the communicative purpose of activities as a second layer of analysis in the normative dimension.

4.2.1 The communicative purpose of design activities (Study B1)

The choice of the ethnographic interview to the double method (Nicolini, 2009) was made in response to the methodological challenge of capture practice, and based on the hypothesis that it would allow practitioners to describe not only the activities they conduct, but also contextualise those activities relationally. In analysing practitioners' accounts of their activities during a workday, the justification for the prioritisation of activities, and the outcomes of those activities, I advanced the conceptual, activity-based model of the design process developed by Purup and Petersen (2020a) in two ways.

Firstly, through reformulating previously defined categories and identifying additional activities. As Figure 4.2 shows, the four redefined categories of activities are: 1) informative, 2) generative, 3) analytical, and 4) communicative. Among the newly identified activities, communicative activities were dominating, highlighting the relational nature of the design work to a greater extent than previous approaches. Especially, they were not limited to meetings, but included informal reviews at the desk of the practitioner, and delivery of documents for municipal approval or compliance with environmental certification. This finding indicates that the relevance of tools should be determined not only through the usefulness of assessment outputs for the individual tool user, but also by the usefulness when circulated among the many actors involved in the design process, shifting the dominating perspective on the emerging design.

Secondly, previous efforts to model the design process through specific activities were advanced through the notion that design activities can be described not only specific moves and actions, but also in terms of their communicative purpose.

Because of the ability of the interview to the double to capture the normative dimension practice by mimicking an instruction-giving setting, it offered insights into how designers justify certain design activities. This means the ethnographic interview method could capture not only the activities of design practitioners, but also the normative justification of the activities within the discursive context of practice. As shown in Figure 4.2, this is an augmentation of previous activity-based models of sustainable building design which considers not only the design moves carried out, but also their communicative purpose.

4.2.2 The relational, frictional design practice (Study B2)

The ethnographic observations in Study B2 were guided by the finding in Study A that a practice perspective has previously been missing, and in Study B1 that communicative activities have a central role in the design process. My observations revealed, firstly, that the design process is highly relational, and secondly, that the relations can be understood through focussing on the frictions that emerge among actors.

The relational nature of design is seen through the detection of 47 distinct actors, who interacted in 682 unique chains of interaction, an overview of which is shown in Figure 4.3. Whereas a conventional view of the design process focusses on how designers generate solutions for a design problem, the communicative activities were seen to serve equally or more to identify the constraints for the design problem. It is when frictions arise in these communications that problems can be identified and managed by design practitioners through a variety of strategies. This is what I refer to as the construction of networks of friction.

Figure 4.4 shows three different networks of friction present in the empirical material: setting a CO₂ target, implementing less climate intensive technologies, and managing complexity. The networks reflect recurring patterns of mediation that reveal how BSA tools can or could fit into the relational networks of the design process. As seen in the figure, patterns of mediation can be related both to learning and communication (epistemic dimension), and to ordering and valuation (normative dimension). Analysing the integration of BSA tools in design practice through patterns of mediation centres the way that the digital interface allows action to flow between human actors like architects, developers, and consultants, and non-human actors like the natural and built environment, regulations and certifications, and systems of software or hardware that formalise certain worldviews. An example of such a pattern of mediation is the recurring references to the environmental certification scheme Svanen observed in the empirical material. In relation to Svanen, the BSA tool can act to 1) determine what is a relevant sustainability criterion to evaluate, 2) determine if Svanen offers a relevant benchmark for that criterion, 3) determine what that benchmark is and how to quantify it, and 4) offer a way of assessing design proposals in relation to that benchmark. In this way, patterns of mediation help the BSA tool developer structure, define, and evaluate features intended to allow those possible actions.

The view of the design process as networks of friction has implications for BSA tools. The tools could mediate the process of detecting and managing frictions by allowing benchmarking of the emerging design proposal in relation to other actors like municipal regulations, environmental certification systems, and organisational

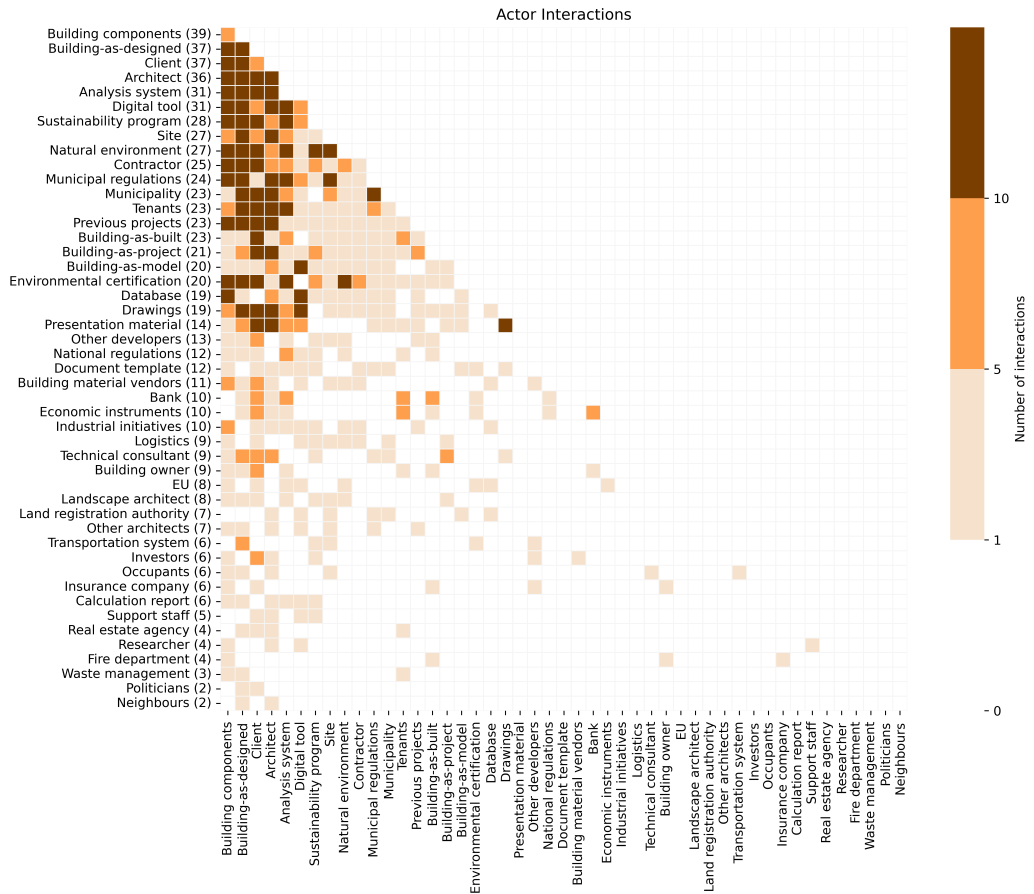


Figure 4.3: Overview of 682 chains of interaction among the 47 detected actors in the empirical material. The count and corresponding hue reflects the number of interaction chains in which two actors coexist. The number in brackets reflects the number of other actors with which an actor coexists.

goals. These systems of governance are identified as especially important for what kind of environmental and social ambitions are possible to realise in a design and construction project. The observations reveal how the centrality of digital interfaces like BSA tools offer them unique opportunities to amplify or challenge prevailing patterns of mediation. Amplifying them, by strengthening existing sustainability discourses, or challenging them, by indicating gaps in dominating systems and identifying voices that are currently missing in design evaluation.

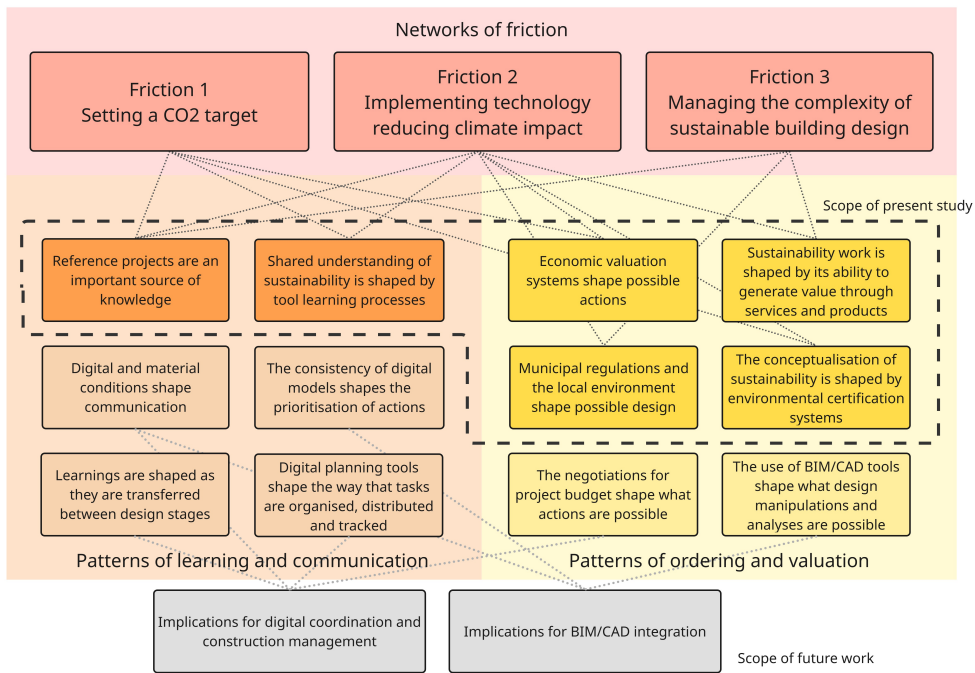


Figure 4.4: Three networks of friction, and two kinds of patterns of mediation identified through ethnographic observations. The figure highlights patterns relevant to the topic of BSA integration in design, but also shows those related to other digitally mediated design work.

4.3 The practice perspective in action (Study C)

Having proposed the methodological and theoretical foundations of a practice perspective on BSA tools, the purpose of Study C was to explore its application in a software development context (Säwén et al., 2026b). I conducted usability testing of a BSA software prototype to explore how to apply a practice perspective during software development. The findings indicate that the practice perspective can be applied by expanding the scope of software requirement specification from considering user-interface interactions to including the relational context in which digital interactions are embedded. The case study followed the development and testing of the Grasshopper-based BSA tool Heath (Säwén et al., 2025), which has the purpose of providing a user-friendly interface for assessment procedures based on Ladybug tools (Sadeghipour Roudsari and Pak, 2013), for energy simulation, embodied carbon calculation, and daylight simulation using early stage design models. Software prototypes were tested with architectural practitioners experienced with integrated design processes.

I found that applying a practice perspective to analyse usability testing data allowed identifying and categorising contextual factors that are often treated as noise in conventional User Experience (UX) analysis. The categorisation of these contextual factors, shown in Figure 4.5 outlines the conceptual reframing from UX to the

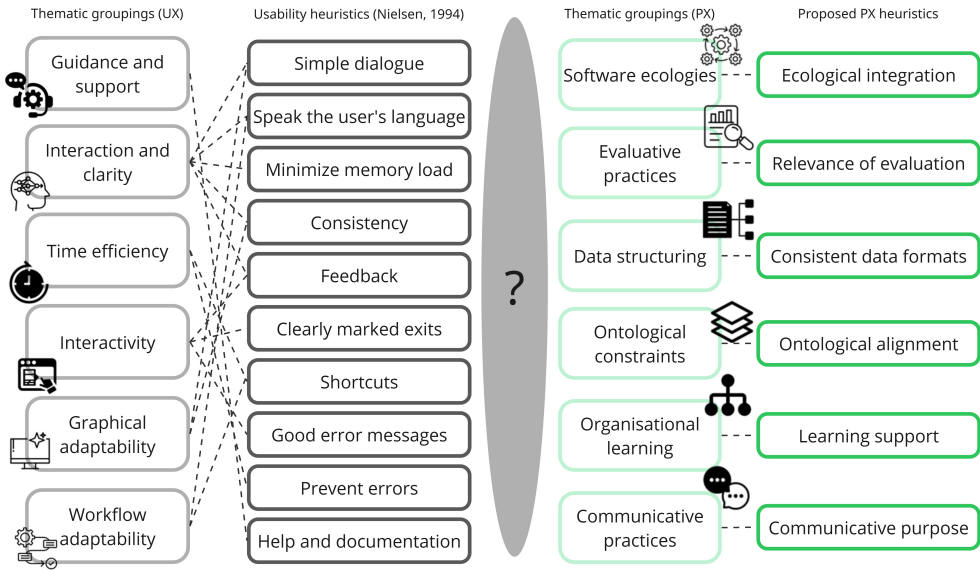


Figure 4.5: Thematic groupings representing User Experience (UX): the individual interactions with the digital interface, and Practitioner Experience (PX): the relational embedding of the interactions in sustainable building design practice. Individual oriented thematic groupings are covered by existing usability heuristics, whereas thematic groupings oriented toward the relational context require the proposal of new PX heuristics.

newly defined Practitioner Experience (PX), shifting the attention from usability to usefulness of digital tools. PX helps analyse the usefulness of BSA tools through six categories shown in Figure 4.5 which describe different ways in which tools embed relationally in the context of sustainable building design practice. *Ecological integration* reflects software interoperability, as practitioners need BSA tools to interact with the CAD system where the design is represented digitally, or external assessment software to which information is transferred for analysis and interpretation. *Relevance of evaluation* reflects the importance of regulatory systems like municipal regulations and environmental certification schemes. When describing their interactions with the digital interface, practitioners consistently refer to the need to carry out assessments or enter data during certain design activities based on the integration of a specific regulatory system in the design case. *Consistent data formats* reflect the need for practitioners to not have to manually filter, clean, and reorganise data. *Ontological constraints* means the representation of a building in the BSA tools needs to match practitioner's conceptual understanding, like making a distinction between internal and external walls in the thermal analysis model. *Learning support* means the software needs to enable learning for practitioners on all levels of the organisation, so that not only the tool operator is aware of tool capabilities and requirements. Finally, *communicative practices* is the settings which determine what the inputs and outputs of tools need to consist of - is the output used for the internal decision-making in the architectural practice, or for the final submission of the project for client review?

Through providing these thematic categories, PX brings together the findings of the previous studies, making the practice perspective actionable during BSA software development by using usability testing data to identify important design activities and how BSA tools embed relationally in those activities. The following section describes the evaluation of Heath based on the thematic groupings of PX.

4.3.1 Appraisal of Heath with practice perspective

The development of the BSA tool Heath, which was used for usability testing in Study C, was carried out mainly from a perspective of improving usability within an educational context (Säwén et al., 2025). The practice-oriented analysis of usability testing data collected during Study C has permitted the appraisal of the current Heath prototype from a practice perspective, shown here organised according to the thematic groupings reflecting Practitioner Experience (PX), found in Study C.

Following the guidelines defined in Study A, the practice-oriented tool evaluation must depart from a clear definition of the intended user, and their goals when applying the tool. As Heath has mainly been developed for pedagogical purposes, the present evaluation assumes the user is a Student with some proficiency in digital design tools, some fundamental knowledge of building physics and industrial ecology. Their goal with integrating Heath in their design process of a small project in a Swedish context is to better understand the consequences of design changes in terms of the sustainability of the building design, and present these consequences in a Master's level course setting.

Ecological integration The Student operates Heath within the advanced 3D modelling environment Rhino, which offers great interoperability in terms of geometry, but also offers modelling capabilities beyond what the assessment model can analyse with precision. In response to this, future versions of Heath need to clearly restrict what kind of geometries can be input, and help the user assess whether the input model is relevant based on the constraints of the assessment system.

Relevance of evaluation The interface offers a variety of energy and daylight metrics, but they are often quite advanced and fine-grained, and difficult to interpret meaningfully. Further, they are not aligned with assessment systems in the Swedish context where the course operates - often Daylight Factor in utilised spaces is used for building permits, a metric not available at the interface. Further, environmental certifications are not included, and there is no benchmarking option. The black-boxed nature of the tool, which is difficult to adapt although implemented in Grasshopper, makes it difficult even for the most advanced Students to align the assessment outputs with the specific needs for evaluating their design.

Consistent data formats The material data entry in Heath is consistent with Swedish data formats like the Climate Database offered by Boverket (the National Board of Housing, Building and Planning). Output data from energy simulations is consistent with conventional format as it is based on EnergyPlus. However, simulation output files are not directly available to the user for processing in external software. Further, for embodied carbon results, the output data is only available within the interface, and cannot be imported in more sophisticated LCA software for further processing.

Ontological alignment The building model capabilities is restricted to one room type, meaning multi-functional buildings are not possible to evaluate. Further, building components can only be defined once, for instance, several exterior walls cannot be combined. In order to allow more complex assemblies and functions for the building, more options are needed. However, such choices need to be implemented with care not to increase the complexity too much.

Learning support The only available support in the interface are help buttons which are complicated and difficult to use. There is no help in interpreting specific inputs, checking whether the model is setup correctly, or in interpreting the assessment results for a Student with limited technical expertise. No manual or walkthrough is currently offered. Currently, the only possibility of learning the software is through video tutorials or in-person tutoring.

Communicative practices Since the goal is a pedagogical exercise in learning the link between design parameters and, the graphical assessment outputs are currently lacking. Either, they would need to offer more options that allow comparing multiple simulations with links to the varied parameters, or they would need to offer more useful numeric outputs so that the Student can create their own visualisations using external tools like Excel.

4.4 Future BSA tool development

While the findings of my thesis have not yet been directly applied to guide software development, I can still draw upon my work to provide some initial directions for the next generation of BSA tools. This section presents three currently unexplored ways for BSA tools to support sustainable building design:

- I. Trace sustainability ambitions
- II. Identify potential frictions
- III. Critically assess normative system

Tracing sustainability ambitions The empirical view from the observation of communicative design activities in Study B2 shows how sustainability ambitions are high at the outset of the project, but that frictions caused by the growing complexity cause the ambitions to be set at the wayside and eventually disappear. Examples from the observations include changes to spatial needs introduced by the complex program, new information on fire restrictions changing the possible material choices, and the shift from discussing an ambitious CO₂ target to setting an ambition level in line with the actors “furthest back in the pack”. The BSA tool could enter this process by tracing early ambitions and allowing them to be documented and reevaluated as the project progresses.

Identify potential frictions The process by which sustainability ambitions are worn down is largely through frictions introduced by actors entering the design process and reconfiguring the design space. The BSA tool could analyse the boundary conditions of the design project in order to identify which frictions are likely to occur later. This would allow negotiations to be informed by and decisions to be evaluated based on the risk of having an impact on sustainability as the building design

improves in detail. The prediction could draw upon previous projects in the office portfolio.

Critical assessment of normative system As the observations and interviews in Study B show, BSA tools act in both an epistemic dimension (providing knowledge) and a normative dimension (providing valuation). The BSA tool could provide a visualisation and critical assessment of the normative system which is emerging through the negotiations among design process actors, indicating gaps and potential alternative perspectives.

4.5 Summary of findings

The studies included in this thesis, and detailed in the appended papers, all deal with aspects of applying a practice perspective to the development of BSA software intended for integration in the early stages of the architectural design process.

The literature meta-review in Study A reveals that the practice perspective has largely been missing in the state-of-the-art of BSA tool research. It provides a characterisation framework that can be applied to understand aspects of tools that can contribute to their success when integrated in design practice. Study B explores activity theory and actor-network-theory as theoretical foundations for the missing practice perspective. It provides activity-based and actor-network-based conceptual models of the design process that can be used to anchor tool development efforts in terms of relevance for specific design activities, and specific relational networks in design practice. Study C makes the conceptual models of the design process actionable in a software development context, by expanding the concept of user experience (UX) to practitioner experience (PX). The study identifies thematic groupings serving as the starting point for the formation of PX heuristics that could augment the understanding of user-interface interactions with a description of the relational context of software integration. The thematic groupings are exemplified through appraisal of the BSA software prototype Heath.

The overall findings of this thesis can be summarised as follows: 1) a practice perspective has been missing in previous BSA tool development efforts, 2) social practice theories and ethnographic methods allow adopting such a practice perspective, and 3) the practice perspective can become actionable in a software development context by considering usefulness for the practitioner in a relational context, not only usability for the individual user.



Vignette 2: Technical solutions proposed by the architect meet resistance from the client, whether they are previously tested, undergoing testing, and yet untested. ©Anton Arnby, 2026, used with permission.

Chapter 5

Discussion

5.1 The missing practice perspective

Study A investigated Research Question A: *What perspectives have previously been applied to digital tools for building sustainability assessment (BSA)?* The literature meta-review showed that the practice perspective has been missing. This section discusses the consequences of this gap, and how to bridge it.

Lack of tool characterisation methodology The literature meta-review reveals a trend in the development of BSA tools from a techno-centric to a user-centric perspective (Attia et al., 2012), that has yet to expand the scope to the relational context of practice in which tool integration occurs. Tool review methodologies lack consistent conceptual frameworks, although examples like Attia et al. (2012) exist. As also found by Donn (2004) and Bleil de Souza (2012), the meta-review shows that evaluations are often based on assumptions about what designers want instead of actual documentation of practice. The characterisation framework presented in Study A provides a way of conceptualising tools from a practice perspective, which could be used as discussion material in interactions with practitioners as part of a software co-design process like the one described by Johansson and Messeter (2005).

Lack of a critical view on design as decision-making In the reviewed literature, design processes are understood as processes of decision-making (Østergård et al., 2016; Nielsen et al., 2016), and digital tools are framed as ways of supporting architects' decision-making (Yu et al., 2022). However, there are no descriptions of what that decision-making looks like - during what activities are what kind of decisions made, by what actors, and based on what kind of information? Ethnographic studies in the field of LCA reveal that the impact of assessment results cannot be specified to originate from a single decision, but from "complex sequences of events that connect products, practices, people, and organisations" (Beemsterboer, 2025). Thus, BSA tools should not be evaluated based on their ability to solve specific well-defined problems and inform specific decisions (Beemsterboer et al., 2025). The practice-informed tool evaluation methodology needs to consider their ability to support issue-raising (de Marinis and Rowan, 2025) and design space exploration (Østergård et al., 2017), and to participate in the network construction that causes

a certain design to stabilise as a coordinated outcome (Bygballe et al., 2016). These gaps identified in the literature meta-review guided the ethnographic approaches applied in Study B. First, focussing on how decision-making becomes part of and occurs through specific design activities; second, rephrasing decision-making altogether into the stabilisation of actor-networks representing certain interests in the design process.

Lack of descriptions of the relational context of tool integration The view of tool integration has mostly been limited to the individual practitioner including assessment software in their existing CAD environment, which is reflected in evaluations of the “architect-friendliness” of tools (Attia et al., 2009; Purup and Petersen, 2020a). However, this view is limited in its ability to explain how tools become useful within the design process, which requires a view on the relational context that constructs that meaning. My observations show, like Cuff (1992) and Ahuja et al. (2020), that by employing architectural practitioners to develop a design proposal, clients are powerful actors in this relational context, who have great say in the negotiations leading to the development of the design project and the normative system evaluating it. My observations of architect-consultant interactions reflect the emergence shown by Negendahl (2015) of different collaborative arrangements between architects and engineers in which tools participate in different ways. In this context, I see like Wallhagen and Glaumann (2011) how assessment frameworks like certification schemes structure the way that architects can work with sustainability, thus shaping the design results. I also observe, like van der Leer (2025), how sustainability assessment work guided by environmental certification scheme is affected by the often voluntary nature of the certification; while schemes can provide inspiration for goal setting early on, they can also be dropped if costs of certification are deemed to exceed the perceived value of the certification.

A recurring actor in my observations is the municipality, reflecting the view of Hewidy (2022) and van der Leer (2025) who investigate how local authorities shape design opportunities through competition briefs and sustainability programs. Similar to Van der Linden et al. (2019), I see how the perspectives of the building occupant, and at larger scale that of the local and global environment, risk being drowned out in this complex network of actors influencing design in different directions. This networked view of the relational context points toward the importance of the BSA tool being developed from and including these perspectives.

The analysis of patterns of mediation in Study B2 indicate that the intertwined work of mapping the constraints for the design problem and identifying potential solutions, contain both epistemic and normative dimensions. As problematised by Beemsterboer et al. (2025), the engineering regime in which BSA tools typically originate is mostly concerned with the epistemic dimension, solving specific problems based on known constraints. My observations show that the communicative work in the design process revolves equally around mapping potential constraints in the normative dimension, developing evaluative criteria for the design, thus negotiating what constitutes sustainable building design, similar to how Schneider et al. (2019) argue that scientific knowledge production is entangled with the production of societal values. In this way, my observations indicate the need to understand the way

that BSA tools act in the design process not only to allow problem-solving (epistemic work), but also to enable issue-raising (normative work).

This overview of the relational context obtained through ethnographic work shows how restricting the analysis of BSA tools to individual user-interface interactions fails to capture how practice, including tool integration emerges relationally. Thus, such a limited scope will have a limited explanatory power in how tools become useful in practice. This finding informed the expanded scope in Study B, focussing on design activities and actor-networks, and in Study C, elevating the view on tool integration from user experience to practitioner experience.

5.2 Applying the practice perspective

Study B responded to Research Question B: *How can a practice perspective show how BSA tools become useful to architectural practitioners?* I explored ethnographic methods of applying a practice perspective, focussing the analysis on design activities and actor-networks in the design process. It was found that an important portion of the communicative activities in the design process was dedicated to the construction of frictional networks by mapping the constraints of the design problem through the detection of frictions.

The importance of communicative activities In comparison to previous activity-based models of the design process (Purup and Petersen, 2020a), the ethnographic interviews carried out in Study B1 revealed the importance of communicative activities. While Purup and Petersen (2020a) detect “argumentative consolidation”, “workshops”, and “social interaction” as examples of what they refer to as “meeting activities”, they do not go into detail in what actors are present at these meetings, what materials are presented, and what the mechanisms of decision-making look like. Similarly, Goldschmidt and Rodgers (2013) describe activities like “studying the brief”, “consulting with others”, and “preparing final presentation”, but does not detail what kind of information exchanges happen during these activities, or how they are crucial in developing a shared view of the emerging design proposal among project stakeholders (Ewenstein and Whyte, 2009).

In my interview study, communicative activities appear as central as they provide the normative justification for design work. This is a key benefit of the applied interview to the double method, as it can help understand how activities are being justified by practitioners (Nicolini, 2009). As Luck (2007) observes, design artefacts such as drawings or assessment outputs are not sufficient to understand the collective knowledge of the project - it is only during conversations about the design that this knowledge can be aligned among project participants (Lawson, 2006). In the observed practice, design alternatives under development are discussed in formal and informal design meetings in the architectural practice, often at the desk of the practitioner using the CAD tool to present the evolving design and sketch. The architectural practitioners also interact with stakeholders external to the architectural practice, including project clients, technical consultants, and building permit authorities. These meetings range from highly formal with a set agenda, to informal, impromptu telephone conversations based on emerging issues.

The importance of informal communications was previously highlighted by Boudeau (2013), who notes that formal coordination systems for design teams tend

to counteract the emergence of informal relations, causing collaborative work to fail. This gains relevance for digital BSA tools if they are intended to systematise interdisciplinary collaboration and achieve coordinated outcomes (Bygballe et al., 2016), without taking into account how, as I observe, those interactions are constructed informally in each project context. Another important aspect is considering the different levels of maturity when comparing the institutionalised practices in construction project management with the emerging practices in environmental management. Gluch (2009) notes that environmental perspectives can “be perceived as bureaucratic nit-picking” when introduced in streamlined construction projects, causing fragmentation of practices rather than aligning them. Such concerns are brought up by clients in the observation study, who fear the introduction of environmental certification systems may cause excessive administrative work, and restrict design options. The findings of Study B, along with these previous practice-oriented research efforts, motivate an increased attention to how relational networks are constructed during communicative activities, and how digital tools contribute to that network construction, highlighting or obstructing environmental perspectives.

Beyond interpersonal communications at formal and informal meetings, my interviews show like Schweber and Green (2026) that communicative activities also include the development of design materials and documentation for submission for regulatory compliance checking, like building permit authorities and environmental certification accountants. These practices are heavily mediated by digital tools, which can provide automated workflows and templates for developing materials effectively. BSA tools mostly appear in practitioners’ accounts in this context - rather than guiding the design, they are being applied to develop the documentation materials demonstrating compliance with energy, daylight, and green area requirements in a process of design-for-compliance, rather than performance-informed-design (van der Leer, 2025).

To summarise, communicative activities are, firstly, central to the sustainable building design process by allowing the collaborative knowledge building that allows exploration of the design space, the importance of which is discussed by Østergård et al. (2016). Secondly, they are multifaceted, ranging from informal conversations at the architects’ desk (Boudeau, 2013), to multi-stakeholder workshops and the submission of documents for regulatory compliance checking, as (Schweber and Green, 2026) show. The identification through ethnographic interviews of the central, multifaceted role of communicative activities as guiding the application of digital tools for sustainable building design motivated the further attention to the digitally mediated collaborative work during the observations in Study B2.

The communicative purpose of design activities My findings support the view of Nicolini (2009), that ethnographic interviews are useful to capture normative dimensions of practice, i.e., how practitioners establish “what ought to be done”, justifying certain activities by invoking specific relationships in the actor-networks of practice. This provides support for the view that descriptions of practice provided through ethnographic interviews should not be considered faithful representations but rather provide an idealised view of what should be considered the “common good” in a given practical situation.

A recurring theme in the interviews is descriptions of design activities both in terms of the specific steps involved, and in terms of the normative justification for engaging in the activity. This is reflected in the extended activity-based model of the design process shown in Figure 4.2, where a sequence of design activities also shows a sequence of communicative needs for the design practitioner. In this way, the practice perspective contrasts with the view of design work as guided by “design thinking” for the individual designer (e.g. Dorst and Dijkhuis (1995)), who instead engages in certain activities within a wider collaborative network. In this way, the findings of the interview study connects the activity-based models proposed by Lawson (2006), Goldschmidt and Rodgers (2013), and Purup and Petersen (2020a), with the view of design work as shared, collaborative construction of knowledge and values, observed by Luck (2007) and Ewenstein and Whyte (2009). This points toward future work evaluating and developing tools being guided by software development paradigms like computer-supported cooperative work (Baecker et al., 1995).

The implication for BSA tools is that they need to be evaluated not from the perspective of how they can inform the individual designer, but also by observing the ways that the designer shares that improved knowledge with other actors in the design practice. It is this kind of communicative activities and conversations that are the focus of the ethnographic work in Study B2.

The frictional nature of design practice When defining their activity-based model of the design process, Purup and Petersen (2020a) include design criteria, the formal and informal goals described by Cross (2007) which allow the evaluation of a design proposal. However, they do not elaborate on the processes involved in the construction and evolution of these design criteria as design activities in their own right. By focussing on the frictions (Rose, 2016) that emerge during communicative activities recorded through the observations in Study B2, I observed that architectural practitioners pay equal attention to exploring and defining design criteria, as they do to proposing design proposals which fit within the design space spanned by those criteria. Indeed, it is when frictions emerge in the design process that the boundaries of the design space become visible.

An example of a friction visible in the empirical material is when conflicting flows between kitchen staff and waste management personnel are discovered during the design of a daycare centre. Another example is when the building permit authorities provide restrictions for the HVAC system performance based on fire regulations, that require reconsidering the co-living housing concept for the building. These frictions emerge during design conversations informed by digital material, and are sometimes resolved, sometimes ignored, sometimes deferred to later design stages (Rose, 2016). This observation mirrors how Cuff (1992) and Siva and London (2011) observe the bidirectional learning process occurring as the architect learns about design limitations from how client responds to design proposals, at the same time as the client learns from the architect about potential design solutions. This process could be understood as the digitally situated construction of a shared representation of the design problem and potential solutions in a given design project context (Le Dantec, 2010). Hardware and software participate in this process, acting by making certain knowledge available at the interface, while human practitioners also takes part by actively interpreting that knowledge (Rose, 2016). Frictions that

occur when the interface does not operate smoothly become a crucial object of study as they make visible the processes of translation and mediation (Latour, 2007) that allow a certain design to be finalised.

The observation of communicative activities in design practice reveals that these activities allow the participants to detect frictions between different actor perspectives, allowing practitioners to apply a range of strategies to resolve them. This work occurs largely at digital interfaces, where hardware, software, and practice coincide to produce a temporary shared understanding of the design situation (Ewenstein and Whyte, 2009). In this way, the design process becomes a digitally mediated process of network construction (Rose, 2016). This indicates that for digital interfaces to be useful in design, they need to be developed with attention to how they can mediate this relational work.

The relational nature of design practice The systematic analysis of the observation material collected in Study B2, detecting the actor-networks involved in design processes, reveals the highly relational nature of design practice, and the embedded nature of digital tools. The most integrated actor is the object of the design process - the building-as-designed and the components of that building. Like Ewenstein and Whyte (2009) argue, this shows that the building-as-design can be understood as an “epistemic object” which constantly unfolds as it is represented through various means and interpreted by the participants in the design process. Like Cuff (1992) observes, I see how the client-architect relation is also central to the networks as it is through their interactions that the design problem, design solutions, and the normative system which can be used to evaluate them, stabilise. The main objective of the client appears to be the economic value generation enabled by the construction project (Harvey, 1978), while systems of governance surrounding the project constrain the ecological and social impact (van der Leer, 2025). The systems of governance include national and municipal regulations enacted by policymakers, environmental certification schemes, and organisational commitments like individual climate goals. Economic instruments and institutions also contribute to enforcing these systems of governance by enabling green stocks and green loans providing economic benefits. Digital tools, both for graphical representation and assessment, become important in the networks as they allow constructing the shared understanding of design constraints (Le Dantec, 2010). Inscriptions like presentation material, drawings, and other documents are the material manifestation of the actors and forces that cause a certain design to stabilise (Lindgren, 2024). The actors also include the eventual occupants of the building, as well as insurance companies, fire department, waste management, who all act through the client and the architect to change the design in certain ways aligned with their needs. To a large extent this action is mediated by digital BSA tools, the use of which is justified through embedding in a relational context composed of a tangled set of tools which formalise the evaluation of sustainability in the design process: legislation and certification systems.

This view, collected observationally, of the complexity of the design process reveals how a multitude of actors are at work, influencing the design in different directions through the translation of other actors - translation which is more often

than not digitally mediated. In this situation, it makes sense that design practitioners turn to digital systems to simplify and systematise this pluralistic perspective (Çıdık et al., 2017), but the digitalisation can only be beneficial if the digital systems are able to represent this wide range of relations. This means the processes of simplification and systematisation by which digital systems operate need to be studied in detail, in order to observe what kind of perspectives are potentially being obscured and silenced.

Black-boxing of building sustainability assessment I can observe a black-boxing process in the empirical material from my observations, when the sustainability program of the client structures the way that environmental and social aspects can be conceptualised. In actor-network-theory terms, this can be seen as a process of black-boxing (Latour, 2007), where initially contested conceptualisations of the world and ways of understanding environmental aspects of the design process stabilise and become difficult to challenge (Lindgren, 2024). Often, the term “this topic is dealt with through our use of Svanen certification” can be heard, for instance in relation to energy performance. This deferment to the certification scheme streamlines operations as analysis is only considered to be needed in later stages to confirm compliance, at which point a HVAC professional will be included in the team of technical consultants. This deferment thus hinders the application of BSA by architectural practitioners in the early design stage, whether or not it could bring performance benefits to the initial design alternatives. Çıdık et al. (2017) describe the process of simplification and systematisation that digital systems require to be able to provide representations of complex reality. Observing BIM-mediated design work, they highlight that this process risks causing “ordering in disguise”, which refers to how digitally mediated changes to design practice intended to streamline workflows and resolve frictions in the design process simultaneously obscure perspectives and silence the voices of those whose systems of work are not aligned with the digitally mediated process (Çıdık et al., 2017).

Thus, the practice perspective reveals how digital tools can contribute to a process of black-boxing where certain conceptualisations of sustainability become difficult to challenge, causing alternative perspectives to be silenced (Goulden et al., 2017). At the same time, digital tools are often highly black-boxed themselves, allowing little insight into their processes of development and inner workings. This indicates that future research into BSA tool integration in practice should highlight what kind of relations are being cemented through certain assessment functionalities being made available to the practitioner. An implication for BSA tools themselves is that, to avoid black-boxing, they need to be transparent and allow the practitioner to scrutinise and question underlying assumptions and normative systems.

5.3 From user to practitioner experience

Study C responded to Research Question C: *How can a practice perspective be applied during BSA tool development?* The practice perspective is made actionable in a software development context through the identification and categorisation of themes not covered by a user perspective formalised by User Experience (UX) heuristics, which could be the starting point for the formation of Practitioner Experience (PX)

heuristics. The proposed PX heuristics go beyond the interactions between the individual and the interface, and instead consider the relational embedding of digital interactions in practice. In this way, PX goes beyond usability to investigate how BSA tools become useful relationally.

Making the practice perspective actionable The main benefit of the expanded scope from UX to Practitioner Experience (PX) is that it captures contextual parameters which may be considered as noise in conventional UX analysis approaches, and instead highlights them as determining factors for the usefulness of tools. This is achieved by emphasising how the practitioner describes the relational context causing BSA tool application to be perceived as meaningful and justified (Nicolini, 2012). Through acknowledging the agency of human and non-human actors in the design process (Kimbell, 2012), PX shows how the digital ontological representation of the building and the assessment needs to be meaningful both to the practitioner involved in decision-making (Bleil de Souza and Tucker, 2015), and to the digital system (Bjørnskov et al., 2025).

The difference between practitioner and user PX distinguishes between the user, who wants to effectively carry out well-defined tasks supported by the digital interface (Wallach and Scholz, 2012), and the practitioner, who requires justification of technology use in the relational context of practice (Nicolini, 2012), in order for digital tools like those for BSA to have practical utility (Beemsterboer, 2025). This shift is crucial because a BSA tool optimised for the efficiency of the single user may still fail to facilitate communication among the stakeholders with influence on building sustainability, like interactions between architects and clients (Cuff, 1992), or between environmental assessment systems (Wallhagen and Glaumann, 2011). A focus on UX may lead to black-boxing of complexity in the name of making the interface architect-friendly (Attia et al., 2009), contributing to the process of “ordering in disguise” described by Çıdık et al. (2017). PX encourages unboxing the assumptions inherent in BSA, allowing the practitioner to critically assess the result and alternative interpretations of sustainability (Goulden et al., 2017). An additional advantage of the practice perspective is carrying out the analysis in the practical context and not in controlled experiments, taking into account and making tangible the messy reality of sustainable building design including the deadline pressures, liability concerns, and negotiation of fees (Dossick et al., 2019). This also offers challenges, however, as the need to investigate tools in a practical context can be more costly than an experimental approach, and the results may be more difficult to generalise because they are retrieved from a specific, situated practice.

Alternative practice perspectives By expanding the scope from usability covered by UX heuristics (Nielsen, 1996), to usefulness reflected by PX heuristics, the practice perspective is in alignment with the Technology Acceptance Model (TAM) (Davis, 1986). However, it goes beyond TAM in its definition of usefulness. TAM bases usefulness off the perceptions of the user, whereas PX understands it through the relational, normative justification of the application of technology which is guided by a complex network of actors coinciding to make it useful.

The expanded scope from UX to PX can be regarded a contribution to the field of Human-Technology Interaction (HTI) (Malakhatka and Wiberg, 2025). PX emphasises how relationships between digital interfaces and human become meaningful and useful through embedding in a relational context. This is in line with service design research (Vargo and Lusch, 2016), which models the value creation of technology on various ecosystemic levels ranging from actor-actor to institutional logics. The service logic, however, presumes a streamlined process which can be optimised, which is not the case for the embodied, non-linear, complex reality of design work (Kimbell, 2012).

Another adjacent research stream is User-Centred Design (UCD) which provides useful guidelines for adapting tools to users with a variety of backgrounds and competences (Wallach and Scholz, 2012). However, the UCD perspective assumes that tools are meaningful and useful, whereas PX highlights the process by which tool application becomes justified relationally.

5.4 Advancing building sustainability assessment

The synthesis of the three studies included in this thesis indicates a practice-oriented direction for the future development of BSA tools, outlining three key ways by which BSA tools could improve in terms of usefulness by embedding in the relational networks of practice: tracing sustainability ambitions, identifying potential frictions, and critically assessing normative systems.

Tracing sustainability ambitions The empirical observations in Study B1 show how sustainability ambitions are high at the outset of the project, but fail to be realised in terms of actual actions, and are worn down and lost through frictions. This could be overcome if BSA tools keep track of goals set at early stages, and allow continuous follow-up throughout the design project so that ambitions are not lost. This would be enabled through integrating the voices of a wider variety of stakeholders than in currently available tools, and a stronger anchoring in local context (Sharifi and Murayama, 2013). Longitudinal studies, as those carried out by Ryd (2004) and Beemsterboer et al. (2025), applying the practice perspective proposed through my thesis to follow tools as they are applied throughout a design process beyond the early stages, could help identify the moments when tools are permitted to act (Haapio and Viitaniemi, 2008), and what mechanisms causes them to fail. Beyond the individual project, an important way that BSA tools could act which is missing in the observed practice is in feeding forward learnings from previous projects as input for future ones (Hiyama et al., 2014). I see in my observations how previous projects are often invoked as examples of when technology transitions have been successful or failures. This indicates, like Beemsterboer et al. (2025) shows, that the main sustainability benefits of integrating BSA in a design process may be not in the individual project, but in the long term organisational learning of the involved actors.

Identifying potential frictions The empirical observations reveal that the complexity of the project increases through friction, causing the design space to unexpectedly shrink, potentially causing costly redesigns. If the BSA tool could identify potential frictions at early stages based on the building program, the relational context,

and learnings from previous projects (Hiyama et al., 2014), it could help avoid costly redesigns in response to changing information. Although experienced architectural practitioners navigate the relational complexity intuitively as part of their skillset (Kimbell, 2012), a digitally mediated analysis of the relational context could help shape a shared understanding of what actors are obligatory passage points (Callon, 1996), and thus help prioritise efforts to maintain sustainability ambitions.

Assessing normative systems As shown in the observations, BSA tools operate in an epistemic dimension, providing knowledge about the design situation, and in a normative dimension, supporting and structuring the evaluation of proposed solutions. In the normative dimension, future tools could have a greater impact through a critical assessment of the emerging normative system that is negotiated among actors. As discussed by Kaaronen (2017), tools can provide affordances that translate ambitions into actions. The included metrics have a great impact on design outcomes (Wallhagen and Glaumann, 2011), as well as the weighting among selected metrics (Iwano et al., 2014). If the BSA could unpack the selection and weighting of metrics as negotiated among actors, it could overcome the prevailing black-boxing of sustainability (Rice, 2011; Goulden et al., 2017), and introduce alternative ways of conceptualising sustainability which operates within alternative boundaries (Pelletier et al., 2019).

5.5 Reflections on research design

Looking back at my research process permits identifying alternative pathways that the research project could have taken. This includes quantitative optimisation, iterative software prototyping, and longitudinal observations.

The theme of quantitative optimisation was included in the initial research proposal, but this pathway presumes an understanding of what kind of practitioner needs the optimisation is intended to solve. Without first applying the practice perspective to understand those needs, the likelihood of optimisation algorithms being useful to practitioners was deemed to be low. In other words, it would not make sense to make optimisation more usable without first understanding how it could become useful.

Another approach would have been to immediately initiate iterative, practice-integrated software prototyping. This could have yielded a more developed software prototype, but would have limited the theoretical contributions in terms of understanding the role of tools in the actor-networks of the design process.

Finally, the ethnographic work could have been conducted over a longer time period, for instance tracing the evolution of a design project over further design stages, and tracking how social and environmental commitments are followed-up as the design progresses. This approach might have provided additional insights into the relational dynamics of the design process, but the findings would have been more difficult to link to the future development of BSA software.

5.6 Limitations

Beyond the literature review, the materials in the empirical data collection is limited to architectural practitioners in Sweden, and to some extent other Nordic countries.

This limits the direct applicability in other contexts, although the practice perspective treats local, embodied, and situated practice as the unit of analysis (Nicolini, 2012), meaning a layer of interpretation is always required when applying the learnings in one practice to the situation in another.

The sampling strategy can be described to a large extent as convenience sampling (Golzar et al., 2022). While diversity was achieved in Study B1 and C through the recruitment of practitioners from different practices, a greater variety could have been achieved in terms of work experience and roles. Since demographic information was not systematically collected or self-reported, these aspects were left out of the analysis, which could yield further insights in terms of the embodied experiences in practice. Due to the sampling strategy, there was generally a preexisting relationship between me and the informants (Garton and Copland, 2010). This offered opportunities to discuss topic in greater depth and with greater candour due to the level of trust already in place between me and the respondents. However, it also risks a potential bias, as assumptions about the purpose of the research project, and the use of an existing shared vocabulary, may have affected the collected data. I navigated this aspect through a reflexive approach (Purup and Petersen, 2020b), challenging the empirical findings and attempting to be aware of potential biases.

In relation to the call of Latour (2007) to “follow the actors”, the empirical data collection has largely been restricted to human actors in their interactions with digital BSA interfaces. A true ANT-oriented approach would pay the closest attention to the digital tools themselves as actors, as Ewenstein and Whyte (2009) and Lindgren (2024) have observed architectural drawings, Schweber and Green (2026) have followed the digital inscriptions in a net-zero energy building project, and Luck (2007) have followed other design artefacts. Following the digital interface in use offers a research avenue of high interest, albeit challenging, as noted by Leszczynski (2018). This indicates that from a research practice perspective, future BSA tools need to afford the researcher/observer ways of tracing their use throughout a design process, identifying the moments when it acts, not only when it emerges in relation to a human user who can be directly interrogated.

The analysis of the usability testing data should be understood with awareness that the data collection occurred with the express objective of exploring a practice perspective in software development. This means that the applicability of PX to analyse any given usability testing data needs to be further investigated, and that the demonstration of its usefulness should be limited to usability testing data collected with a practice perspective already in mind.

The perspective applied in my thesis is that of sustainable building design practice and the architectural practitioner. Although my contribution is a way for software developers to understand and express usefulness through identifying the relational context of BSA tool integration, my work does not directly study software development practice itself beyond that which is integrated. This means it does not approach the relational context which makes software development possible, like funding opportunities, marketing, etc. That said, the practice perspective introduced in my thesis could potentially yield insights into that relational context if applied to software development practice itself.



Vignette 3: Activities advancing the design compete with those supporting technical evaluation within the tight schedule of the architect. ©Anton Arnby, 2026, used with permission.

Chapter 6

Contributions

In this thesis, I combine qualitative methods in order to propose a practice perspective on digital BSA tool integration in building design. I propose practical ways of defining software requirements based on a practice perspective, by providing a tool characterisation framework, a set of qualitative methods to learn about activities and actor-networks in practice from practitioners, and a conceptual reframing from user experience to practitioner experience. This chapter outlines the theoretical and methodological contributions, as shown in Table 6.1, and indicates practical implications of the work.

Table 6.1: Overview of contributions.

Research Question	Contributions	
	Theoretical	Methodological
What perspectives have previously been applied to digital tools for building sustainability assessment (BSA)?	Tool characterisation framework	Tool evaluation methodology
How can a practice perspective show how BSA tools become useful to architectural practitioners?	Communicative purpose of design activities Epistemic and normative dimensions of design	Ethnographic interview method Networks of friction
How can a practice perspective be applied during BSA tool development?	Practitioner experience (PX)	PX analysis of usability testing data Potential PX heuristics

In working with qualitative methods, it has been important to apply a reflexive stance to the ongoing research (Nicolini, 2009; Purup and Petersen, 2020a), and to reflect on how I position myself as a situated researcher, relying on experiential acquaintance with the contexts in which knowledge is produced (Kaszynska and Kimbell, 2025).

In Study A, I draw upon the research literature guiding the development of BSA tools. In Study B, I use theories from social sciences and design studies to apply a *practice perspective* to the use of BSA tools among architectural practitioners. This also provides a view of the relational context of BSA integration, which includes both the analytical foundations in environmental science and building physics, and socioeconomic and material context in terms of actors participating in design practice. In Study C, I then draw upon HCI-informed methods to extend them from only considering usability to also have a practical way of investigating usefulness.

6.1 Theoretical contributions

Based on empirical observations of architectural design practice, my thesis builds theory supporting a practice perspective on how BSA tools embed in the relational networks of practice. This contributes to practice theories by adapting them for software development in an architectural design context, emphasising how tools simultaneously shape and are shaped by practices. The work also contributes to software development theories by expanding the analysis scope from individual user-interface interactions, to describing how those interactions are made possible by embedding in and reconfiguring existing relational networks.

In more detailed terms, in Study A I have found a conceptual framework for tool characterisation with a practice perspective. The framework includes analysis capabilities, information management, user interface, design support, and practical integration. The study highlights how insights can be gained by understanding tools not only from the perspective of the interactions between the individual user and the interface, but also from the perspective of the relational context in which tool embedding takes place.

In Study B, I extend previous activity-based models of the design process by highlighting the communicative purpose of design activities, and by recategorising activities as informative, generative, analytical, or communicative. I highlight the dynamic nature of the process, where designers quickly navigate between activities based on emerging knowledge. Design alternatives and an evaluative framework for the design are developed simultaneously, highlighting the epistemic and normative dimension of design. I further propose patterns of mediation as an analytical unit to show tools embed in these intertwined knowledge production processes. Understanding the design process through patterns of mediation reveals how tools cause certain actors' voices to be included in design evaluation, while others are silenced.

In Study C I contribute to software development theories by expanding the analytical scope from user experience to practitioner experience. This expanded perspective acknowledges the active role of tools in shaping the actions of practitioners, adding relations and activities as contextual factors that mediate interactions. In this way, affordances are reframed from being latent properties of user-interface interactions, to being produced through social practices relying on specific actor-networks and activities.

6.2 Methodological contributions

The overarching methodological contribution of my thesis is a consistent method for practice-oriented software development which integrates approaches of collecting qualitative data and analysing them thematically, offering a practice perspective that can inform how tools become embedded in practice. The studies included consistently apply an iterative, inductive coding approach to understand evidence about software integration in practice collected through ethnographic methods. The methodology is shown to offer insights about the relational practice context of BSA tool integration that can be used to inform practice-centric software development.

In Study A, I provide a method for evaluating tools with a practice perspective, offering a set of questions and characterisation criteria that can expand the evaluative scope from the perspective of individual user interactions with technology, to the factors that determine usefulness in the practical context.

In Study B, I adopt the ethnographic interview to the double method for use in a software development practice, highlighting its ability to capture a normative view of practice. This permits identifying how practitioners establish “what ought to be done” in a given relational context, and also allows a view of how practitioners understand activities, the motivations underlying those activities, and the way that tools allow those activities to be carried out. Further, through Study B I also propose an actor-network based method of analysing interactions in practice, which firstly highlights the importance of non-human actors, and secondly allows visualising relations through a matrix-based approach.

In Study C, I initiate a heuristics formation process which adds to software development methodologies by expanding the analysis of usability testing data for software evaluation, from a user experience perspective covering user-interface interactions, to a practitioner experience perspective which also includes relational, contextual factors.

6.3 Practical implications

The findings in my thesis are primarily intended to inform BSA software development intended for integration in early-stage architectural design. This focussed yet interdisciplinary scope means the practical implications are multifaceted, and can be seen both for future BSA practice, software development practice, and architectural design practice.

Firstly, the findings have implications for how software becomes embedded in practice. The included studies observe tool adoption processes, and note that while previous research has highlighted factors that enable individual users to adopt tools, successful integration requires changes to practices and awareness throughout organisations. The findings encourage studies of how tool adoption is made possible in practice by a learning process at different levels of the organisation. This means that tool developers need to consider software requirements not only from individual users but from a wider set of actors who need to adapt practices based on software integration. It also means that practices wishing to integrate software like BSA tools need to be prepared for organisational learning on multiple levels, not only relying solely on individual, motivated users to spearhead software integration.

Secondly, there are implications for the software development practice itself. The expansion of the analytical scope to include a practice perspective means software developers need to consider the application of novel methodologies that can help applying the practice perspective. The thesis showcases how ethnographic approaches can provide a view of practice that is useful to guide software development by focussing on detecting important activities and actor-networks in practice. By increasing the awareness of this relational context, software requirements can be defined that either align with and amplify existing patterns of mediation in cases where they are considered beneficial, or challenge and reconfigure those patterns when they are considered to be opposite to desired design outcomes. This expanded relational perspective also allows software developers to reflect on the black-boxed nature of many assessment methodologies which is persisted through the simplification and systematisation of software solutions. By opening up these black boxes, the embedded values and actor-networks can be made visible, allowing an understanding of what perspectives have been dominating the BSA discourse, and what other perspectives may have been silenced.

Thirdly, the relational context of software integration includes the multi-level systems of governance that control what kind of practices are possible in the built environment, and by expansion, what kind of software integration becomes meaningful. The observations reveal how practitioners navigate a network of transnational, national, and municipal regulations that shape design possibilities in certain ways in conjunction with voluntary environmental certification schemes. It was observed that software integration enables stronger commitments to be made in early design stages, but that there are limited mechanisms to follow-up those commitments and transfer knowledge about design constraints to later design stages. If early-stage commitments are to have an impact on the actual construction practice, mechanisms that trace those commitments are needed, both as the design evolves in the detailed design, during construction, and even once the building is in use. Such mechanisms could improve accountability from the initiation of a construction project throughout its life-cycle, avoiding high ambitions falling by the wayside due to economic considerations.

Chapter 7

Conclusions and future work

I have explored how the usefulness of digital tools for Building Sustainability Assessment (BSA) can be understood through the relational context of tool integration in practice. I show how a practice perspective has been missing in previous development efforts, and provide the theoretical and methodological foundations for its application. Through ethnographic methods, I show that the design process cannot be seen as a sequence of discrete decisions to which tools contribute by providing scientifically accurate information, but as a constant production and reproduction of relations during various activities, utilising frictions within and among actor-networks to establish shared knowledge and values about design constraints and possible solutions. I make the practice perspective actionable through proposed heuristics which allow software designers to tackle the complexity of tool integration, observing how BSA tools become useful by shaping conversations, spotlighting certain perspectives, and silencing others. I propose that the practice perspective can highlight normative aspects of BSA tool integration in the design process. Through the practice perspective, current design practices can be described, deconstructed, and challenged in terms of their ability to produce and reproduce a built environment that provides a social foundation while remaining within planetary boundaries. If developed with this attention to how digitally mediated design practice is co-produced by hardware, software, and humans in a relational context of the social, natural, and built environment, the next generation of BSA software can be foundational to the socially just transition of practices in the built environment in response to the ecological emergency.

7.1 Future research directions

The practice perspective proposed in thesis for BSA tool development points toward several possible research directions, including: a shifted geographical and temporal scope; a stronger focus on non-human actors in ethnographic studies; a consideration of LLM-mediated design processes; the consideration of a wider scope of practice including urban planning, property development, and policymaking; and a larger-scope software co-design process applying the proposed practice perspective.

Geographically, the empirical foundation the thesis is primarily concentrated to Swedish design practice, and secondarily to Nordic countries. Carrying out similar

ethnographic studies in different national contexts, both in Europe and worldwide, could yield additional insights and reveal differences in terms of the organisation and composition of design practice. The thesis also limits the scope temporally, considering tool integration in early architectural design stages. An expanded temporal scope that extend to planning stages even before architects get involved, and trace how digital tools could mediate the evolution of design constraints into later design stages, construction, and use, would allow capturing ways that decisions are stabilised, modified, or lost as the design progresses.

The ethnographic interviews and observations carried out in this thesis emphasise digitally mediated communicative activities, but capture patterns of mediation mostly through the observation of human interactions. The actor-network-inspired approach applied in this thesis could be strengthened further by paying closer attention to the digital tools themselves. Although methodologically challenging, observing digital tools-in-use by architectural practitioners in activities beyond the communicative setting could reveal how actions are selected, and what perspectives are being permitted to be taken into account at the digital interface. This represents a further step heeding the call of Latour (2007) to “follow the actors”.

The rapid emergence of workflows supported by Large Language Models (LLM) has not been covered explicitly in the empirical material collected in this thesis project, but can be expected to change digitally mediated design practices greatly in the near future. During this transition, the practice perspective proposed in this thesis allows posing several key questions, for instance: what kind of actor-networks are being black-boxed as LLM usage becomes more prominent?; what kind of activities are being transformed through the application of LLM workflows?; what perspectives are being elevated and silenced as part of the rapid transformation of practice caused by the introduction of LLM workflows? The network-oriented approach applied in this thesis could also be used to inform the exploration of agent-based approaches to leveraging LLM for design and BSA applications.

This thesis observes the design process mostly from the vantage point of architectural practitioners. However, as observed in the ethnographic study, a wide range of human and non-human actors are involved in and affected by the design process. Today, many of the interactions with the built environment are digitally mediated. Hence, the practice perspective on digital mediation of BSA tools could be applied to other practices, including the work of transnational, national, and municipal legislators, property developers, environmental agencies developing certification schemes, technical consultants, and even residents and inhabitants of the built environment.

Finally, the findings of the thesis are intended to be useful for software development, but the validation of the proposed methodology is limited to early-stage prototyping. Hence, applying a practice perspective throughout a longer-scale, iterative software co-design and development process would yield further insights into how an improved understanding of the relational context of software application can inform the definition of software requirements and the practice-embedded evaluation of software prototypes from a perspective of usefulness in sustainable building design practice. Further, the practice perspective could, if applied to software development practice itself, yield insights into how it is being enabled by funding opportunities, marketing, access to potential users, and further aspects of the relational context.

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