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Demands, default options and definitions: How artefacts mediate sustainability in public housing projects in Sweden and Cyprus

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ABSTRACT

Sustainable building design practices are influenced by requirements, guidelines, criteria for green procurement and certification, assessment tools such as life cycle assessment, etc. This study investigates how such artefacts support or define aspirations towards sustainability, through case studies of public housing projects in Sweden and Cyprus. The study first illustrates how constraints mediated by artefacts set boundaries to the range of available sustainable design options. On one hand, fulfilling sustainability requirements conveyed in regulations, certifications and directives is a major driver of designers' involvement with sustainable design. On the other hand, cost calculations, procurement laws and development plans exclude certain design options. Moreover, default solutions and standardised design guidelines within the organisation streamline and simplify the design process, indirectly determining what sustainable design options are considered. However, these demands and default options are also bent and adapted on a case-by-case basis. The ways in which sustainable design arises from the interplay between artefacts and actors' agency differed significantly between the Swedish and Cypriot cases. Swedish actors' operational definition of sustainability is strongly codified and enforced through interconnected artefacts. The Miljöbyggnad certification is often a de facto definition of sustainability used by actors to set sustainability criteria and targets. Environmental databases for construction products act as black boxes, implicitly determining what aspects of sustainability are addressed in design decisions. Conversely, Cypriot designers' work with sustainability depends to a larger extent on their motivation, experience and ability to convince their peers.

1. Introduction

Buildings are major hotspots for energy use, climate change and resource depletion [1]. The design of buildings to minimise these impacts is therefore an increasingly important concern in policymaking, planning and procurement. Numerous policies and regulations address the energy performance of buildings [2] (e.g. the EU Energy Performance of Buildings Directive) and environmental impacts from construction materials [3]. Several countries (e.g. France, Sweden, Denmark) are introducing mandatory declarations and regulations for the climate impact of new buildings. Additional sustainability objectives are sometimes set in local development plans [4] and through green procurement criteria [5]. These efforts have been accompanied by the development of methods and tools to assess environmental performance. Early assessments focused solely on operational energy performance. However, tools assessing the environmental impacts of materials and construction processes through life cycle assessment (LCA) are becoming increasingly widespread [6–8].

While new requirements, guidelines, certifications and assessment tools for energy- and environmental performance will likely influence design decisions, previous research suggests that their effects will depend on the implementation context, including multiple institutional, social and organisational factors [5,9–13]. For instance, the effect of assessment tools depends on their embeddedness in a community of practice [12] and specific ways of talking about energy targets can perpetuate implementation issues for energy policies [14]. Schröder [15] argues that multiple processes operationalise and give meaning to the concept of sustainability in building design, involving highly contested questions regarding what sustainability issues should be addressed, how this translates into concrete practices, and which actors are responsible. This indicates a need to understand how a building's environmental performance arises from design processes, in order to

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best implement tools such as LCA in building design, certification, procurement and regulation.

The study presented in this paper investigated the key factors and decisions influencing sustainability in recent public housing projects in Cyprus and Sweden. An underlying purpose of the study was to understand how to leverage decision support tools such as LCA to improve energy- and environmental performance in construction projects. Over the course of the research, a key theme arose: the influence of requirements, guidelines, tools, design templates, and other ‘artefacts’ in supporting, limiting or shaping aspirations towards environmental sustainability.

2. Literature review

Previous studies attempting to understand design processes, and in particular building design, have identified a broad variety of roles played by artefacts. The concept of boundary object [16] is commonly used when an artefact creates common ground between different actors, by being meaningful for but interpreted differently by each actor. Boundary objects provide a shared language, concrete ways for actors to understand each other's perspectives, and a reification around which to construct shared meaning. However, artefacts have been shown to play multiple other roles in design processes, including scripting actions, creating or blocking options, providing knowledge or inspiration, constructing meaning, coordinating and organising work, and archiving design decisions [16–19]. This apparent diversity of roles can be explained by two factors. First, different studies consider different types of artefacts, actors, and design situations. Second, studies differ in their analytical lens and the type of effect they consider (on knowledge, power, etc.). Therefore, it is important to specify the types of artefacts, actors, design situations and analytical focus in both previous studies and the present study.

Narrowing down the scope to building design, many studies have focused on the roles played by representations of the building, such as models and drawings, in architectural practices [20–24]. A recurring idea is that the designers' understanding of the building is not constructed through a fully logical and linear process, but is instead constantly in flux and mediated through the interaction between designers and representative artefacts. For instance, ethnographical observations from Yaneva [21] and Comi et al. [23] exemplified how the use of visual artefacts, and conversations surrounding them, allow designers to transform their knowledge of the building. Tryggestad, Georg and Hernes [24] drew on actor-network theory (ANT) to show how sketches, drawings and models transformed a project's goals by supporting and challenging important design choices throughout the project.

Further insights on the roles of artefacts in building projects can be gained from considering actors other than the architect, and artefacts other than representations of the building. Schmidt and Wagner [25] showed that representative artefacts are interrelated with “coordinative artefacts” (including standardised formats, classifications, material catalogues, binders, etc.) to form complex systems enabling cooperation and coordination. Pierce Meyer [17] considered how all artefacts created through architectural practice (including drawings, models, specifications, contracts, spreadsheets, notes, etc.) enable communication between designers, provide evidence of past negotiations and decisions and record the history of design decisions. Focusing instead on the construction company, Styhre and Gluch [26] showed how internal platforms of standardised design practices facilitate knowledge management. Expanding the analysis to planning authorities, Rydin [27] considered how highly detailed policy and planning documents allowed a municipality to direct other actors and govern from a distance. Accordingly, the present study uses a broad definition of artefacts including drawings, software tools, databases, standardised design guides, development plans, directives and regulatory requirements. The fact that such artefacts influence building design is well documented. However, most previous studies do not show specifically how these artefacts influence sustainable design practices, or how they could be leveraged to promote sustainable design. The lens of our study will focus on artefacts' influence on building sustainability.

Previous studies on this topic have often focused exclusively on sustainability assessment tools and standards. Studies of tools such as LCA have often addressed technical aspects, with the underlying argument that using such tools rationally in early project stages would promote sustainable design [9]. However, some recent studies consider more critically how such tools integrate in organisational processes [13,28–31]. Beemsterboer et al. [31] argued that LCA faces a messier context, and more uncertain and varied processes within a building project than in other use cases. Palm and Reindl [30] showed that even when specific tools are used to optimise energy performance, these calculations bear less weight in design decisions than the practitioners' know-how, experience and heuristics. Brismark et al. [28] identified a few very specific decision contexts in which LCA can support sustainable design within Swedish single-family housing companies, including the development of building systems and house models, the selection of products from subcontractors, and dialogues with clients. However, these effects depend on the context and type of project studied. Therefore, there is a need to better understand in which decision situations and through which features appropriate tools could support sustainable design.

Furthermore, insights from the sociology of standards and quantification suggest that the effects of sustainability assessment tools and standards go beyond the optimisation of design options [32–34]. They can for instance elicit action through their organisational features. Eidenskog [35] and Niskanen and Rohracher [36] showed that successful low-energy design required an integration of energy models into organisational processes that can mediate communication between architects and engineers. Schweber [12] and Goulden et al. [37] argued that the success of green building standards such as LEED and BREEAM depends on their organisational features, performative aspects, and ability to coordinate communities of practice. Other studies have drawn attention to the fact that sustainability assessment tools grant legitimacy to particular options or actors and highlight particular issues, while silencing others [32–34] Rydin [27] and Eidenskog [35] showed how assessments of energy- and environmental performance create black boxes, i.e. areas where previously contested assumptions and relationships become taken for granted, and their underlying complexity becomes invisible. Georg [38] showed how a sustainability assessment tool in a development competition was used to grant legitimacy to certain designs. This tool localised the global concept of “sustainable city”, circulating a technical understanding of sustainability that makes some aspects visible and others invisible. Faulconbridge [29] also highlighted tensions between the standardisation of sustainability assessment tools and the local sensitivity of sustainable design. Therefore, it is particularly important to understand how artefacts influencing sustainable design interact with their local context, especially as there is a push to implement harmonised guidelines, tools and policies for sustainable design within the EU. We address this need by analysing side by side and comparing cases in Sweden and Cyprus. Furthermore, while previous studies concerned with sustainable design have mostly focused on sustainable design tools and standards, we aim to account for the influence of multiple types of artefacts on environmental performance.

Finally, our study focuses on one particular type of project where artefacts influence sustainable design: public housing projects. Public housing is usually meant to be affordable. Some countries have “social housing” schemes, although this term is not used in Sweden or Cyprus. Public housing design has been rather neglected in previous research. Many studies tend to focus on flagship architectural projects with unique designs (e.g. a museum [17], a skyscraper [24], office towers [27,39], a concert hall and train stations [39]), whereas public housing projects usually entail more standardised designs and functions. Luck [20] and Niskanen and Rohracher [36] did study public housing projects, but focus on particular cases in which houses are co-designed with users, or designed according to passive standards, respectively. In contrast, our study aims to shed light on more widespread public housing projects.

The present study contributes to the growing corpus of research on the roles of artefacts in building design in three main ways. First, it is purpose-driven and focuses on how artefacts shape sustainable design, encompassing all artefacts and decisions that significantly influence the building's environmental sustainability. Second, it focuses on a widespread, relatively standardised and neglected type of project: public housing. Finally, its transnational comparison of cases provides insights on the importance of differences between local contexts.

3. Method

The original design of the study, the rationale for case selection and the data gathering procedure aimed to investigate factors influencing environmental performance in public housing projects in Sweden and Cyprus. The focus on artefacts arose later during data analysis.

3.1. Case studies of public housing projects

Case study research provides qualitative insight into the studied phenomena in their real-world setting [40,41]. It is appropriate to build up in-depth, context-dependent knowledge, provide rich accounts and narratives, and possibly identify "black swans" that a broader study might miss [42]. The rationale for case selection depends on the study, and cases may be selected because they represent extreme values or maximise variation along a certain parameter, or because they exemplify a broader category [42,43].

Four recently completed public housing projects were investigated, two in Sweden and two in Cyprus. These two countries were selected to maximise variation in a European context, thereby providing insight into the diversity of design situations and how these might depend on the national context. The countries differ notably in their approaches to urban planning, public housing, as well as environmental and building-related regulations. Sweden follows a comprehensive spatial development approach with a system of national- and local-level rules and regulations, including environmental requirements [4,44]. Cyprus, on the other hand, has influences from the Mediterranean urbanism tradition, more ad-hoc development decisions and clientelist relations [45]. Focusing on public housing allows a comparison of housing types serving similar purposes within and between countries. In Sweden, municipally owned real-estate companies (MRECs) have a mandate to provide affordable rental housing. In Cyprus, the national land development association (NLDA) operates under the Ministry of the Interior and sells affordable plots or housing units to low- and medium-income applicants.

In Cyprus, one project was selected to represent traditional, mainstream practices in the organisation (CY1) and the other to represent more recent perspectives putting quality and environmental performance on the agenda (CY2). In Sweden, the intention was to follow a similar rationale. A "best practice" and a more mainstream case were selected, but the "best practice" case led to major setbacks and key actors could not be interviewed. Due to pragmatic concerns, this case was replaced, and both Swedish cases (SE1 and SE2) are rather mainstream, although both have environmental ambitions above legal minimum requirements.

3.2. Data gathering and analysis

Data was gathered through interviews with practitioners and documentary analysis. Semi-structured interviews were conducted to collect open-ended data and gain an in-depth understanding of the respondent's perspectives [46]. The interview template addressed the background of each respondent, their role in the project or the organisation, how decisions are taken within the organisation and the case study project, their views on what constitutes "high environmental performance" and related notions, and what decisions influence a building's environmental performance. Respondents were also asked about their experience with LCA and other decision support tools, and whether they felt these could be implemented within the projects they worked on. The template is provided in Appendix 1.

The participants were selected based on indications from project documents and other interviews (snowballing approach), as well as previous literature on key actors for sustainable design [47]. Interviewees included stakeholders involved in various stages of the projects, as well as managers and administrators from each housing organisation (Appendix 2). The interviews, of approximately an hour each, were conducted in 2020, on the phone or over video calls, due to the Covid-19 outbreak. Interviews were conducted in the interviewee's native language, then transcribed and translated into English. One of the authors conducted the Swedish interviews and another the Cypriot interviews. Interviews were first analysed by the person who conducted them, and the translations were then read by the other interviewer to conduct a joint analysis.

Documentary analysis was conducted both before and after the interviews. Before the interview, documentation was gathered for each case, including drawings and models, internal communication documents, participant lists, design guidelines and energy performance certificates when applicable. After the interviews, additional documents mentioned by the interviewees or highlighted by the preliminary analysis were analysed. This included an overview of the detailed development plans and municipal design program in Sweden, the strategic development plans and zoning plans of each area, and policy statements from the ministry of the Interior in Cyprus.

The analysis followed closely the empirical material to describe the design process in each case and to identify key decisions affecting environmental performance. Common themes were identified for further analysis. The focus on artefacts mediating sustainability arose through induction early on. Subsequently, the analysis focused on describing interactions between human actors and artefacts in these key decision situations. The study was part of a research project with an overall focus on understanding how tools such as LCA could be best implemented to support sustainable design. This coloured the initial perspective of the researchers, but was not an overt focus of the analysis.

4. Description of the cases

4.1. Description of the Swedish cases

Both Swedish cases SE1 and SE2 are rental housing projects, initiated by municipal real-estate companies (MRECs) on land owned by the MREC. SE1 comprises eight multi-family buildings, located in an urban area in a municipality of around 150,000 inhabitants. The project started at MREC1 in late 2016, and the last tenants moved in in early 2021. SE2 comprises six detached multi-family buildings and is located in an urban area in a municipality of around 100,000 inhabitants. The project started at MREC2 in 2016 and was finalised in 2019.

Swedish municipalities play two important roles. As public authorities, they handle all matters related to planning, including development plans, exploitation agreements and building permits. Furthermore, they own significant amounts of land and buildings. MRECs, owned by municipalities, own and operate about half of the rental apartments in Sweden. As public authorities, municipalities must comply with the national Planning and Building Act and enforce the building code, but as property owners they are free to set additional requirements [3].

The origins of both projects can be traced back to decisions from the MREC's political board. The board receives owner directives from municipal politicians. These directives occasionally include sustainability targets. The board interprets the directives and sets the MREC's overall strategy and internal targets to fulfil the directives. Technical managers in the executive group work to implement this strategy. For instance, MREC2 received a directive about prioritising wooden frames and established an internal objective of conducting two wood-construction projects per year.

In the first stage of both projects, the MREC acquired land from the municipality and practitioners developed early design proposals. In SE1, the head of construction, the sustainability strategist and a consulting architect discussed possible developments. In SE2, the project leader conducted a pre-study to get an approval from the executive group. Practitioners interpreted requirements from municipal development plans, regarding the height and density of buildings, daylight, noise pollution, etc. In addition to development plans, the municipality at SE2 had an overarching design program describing design guidelines for all new buildings, including material choice for the facade.

In both cases, the project leader and consultants then developed tender specifications and applied for a building permit. The procurement form, *totalentreprenad*, meant that the contractor was responsible for the final detailed design and its implementation. However, most of the overall drawings and important design choices were made by the client and consultants before procuring the contractor. Therefore, the layout of the building, the type of material used for the facade and the roof, etc. were to a large extent already set in the tender specifications. At this stage, the project leader at SE1 applied for energy performance subsidies from the county administrative board.

Both MRECs have internal documents describing default design solutions and criteria for all new construction projects, including material choices and criteria on energy performance and local environmental impact. They are called "construction handbook" at MREC1 and "design directions" at MREC2. These documents were used by project leaders and architects to develop the tender specifications, and by contractors to finalise the design. Both documents require the selection of construction products with a high enough "sustainability grade" from a third-party database of environmental impacts. This grade is based on criteria primarily related to local environmental and human toxicity.

The handbook at MREC1 requires designers to follow the criteria of the Swedish Miljöbyggnad certification, performance level Silver, except for energy use where a separate criterion is used [48]. Similarly, the board of MREC2 previously decided to certify all new buildings with Miljöbyggnad Silver, in order to fulfil a directive from the municipality about being at the forefront for environmental sustainability. As mentioned by a contractor, the Silver level is widespread in Swedish construction projects, while the Gold level is mostly used for ambitious flagship projects.

Once the building permit was obtained and the tender specifications were approved by the board, the MRECs put the contracts out for tender. Contractors developed tender proposals, which were evaluated by the MRECs. In both cases, the cheapest offer was chosen, and discussions took place between the MREC's project leader and the contractor's representative to reduce costs further. The board of the MREC approved investment decisions, based on a calculation of return on investment in a 10 or 15 years' time horizon. The project then entered a post-procurement design phase, where the contractor finalised the design, the specification of construction products and the placement of pipes, cables, ventilation shafts, etc. The contractors followed the tender specifications and the MREC's design directions, but could propose minor modifications, subject to the clients' approval.

4.2. Description of the Cypriot cases

Both Cypriot projects CY1 and CY2, comprising dwellings to be sold to low- and medium-income households, were developed by the National Land Development Association (NLDA). CY1 is the second phase of a large project, which includes 15 semi-detached houses in a rural area, near a village of 4000 inhabitants. This represents a common project type for the NLDA, i.e. in-house design on own land and involvement of contractors only for the construction stage through traditional procurement and construction contracts. Tenders were submitted through the national procurement system and the contractor was appointed in 2017; the tenants moved in in 2020. CY2 comprised apartment buildings in an urban area, in a district of 17,000 inhabitants. It represents a different approach, where the design was outsourced through an architectural competition in 2020. As of Spring 2022, the project is in the detailed design stage.

Cyprus suffered a severe housing shortage as a result of the 1974 Turkish invasion. To address this issue, the government introduced urgent initiatives to speed up new construction, positioning the building industry as a key actor in the Cypriot economy. The government avoided the introduction of binding requirements to protect the physical and cultural environment, taking instead ad hoc decisions when such issues came up. Nowadays, the only binding requirements are those required in EU regulations, including for example the Environmental Performance of Buildings Directive (EPBD). Local development plans exist for urban areas, but not for all rural areas, where development is covered under a generic 'policy statement'. In 1980, the government established the NLDA, tasked to provide affordable housing following governmental strategies.

Initial directives for new projects at the NLDA are usually given by the Ministry of the Interior to the Board of Directors, representing political parties. A directive might set targets for new housing production or related to the public image of the NLDA. Alternatively, the directive might simply approve a budget and development plan proposed by the NLDA's Board of Directors; this was the case for CY1. The Board of Directors is then responsible for converting these directives into policy decisions and planning the implementation of those decisions, often with the support of in-house managers and technical experts.

The design of CY1 was carried out entirely in-house. Initial directions, such as on possible locations, were given by the management of the NLDA to the technical department. The in-house architect and design team first estimated the number of units that could be developed in the plot and the overall layout of the project. The layout was to a large extent determined by regional contextual limitations such as local height and coverage factors from the national zoning plan, as well as internal design guidelines. Throughout the design process, designers also considered information from other designers and feedback from the sales department, communicated either verbally or through internal memos.

At later stages of the design, the architect selected materials and optimised the layout and orientation. Other consultants handled the structural, mechanical and electrical designs, the energy certification and the detailed specifications, following the overall design of the architect. Frame types and materials were standardised and decided from the beginning. Previously, the organisation had standardised drawings and specifications used identically in every project. While these are not applied directly anymore, a standardised typology still exists, including typical drawings and indications for the structural design, the frame type and the materials used. The NLDA also has an internal database of technical specifications and previously selected solutions. When departures from this internal database happen, the database and typology are updated to include the latest materials, systems, drawings and specifications used in the design. In the case of CY1, no major departure from these standard solutions was made. The choice of technical systems was primarily taken from the database of technical specifications, although some market research and cost-benefit analyses were also conducted. Based on the final design, detailed drawings, bill of quantities and tender specifications were provided to potential bidders. No change in design took place after the start of the procurement phase, and the lowest tender price was selected.

CY2 represents a different approach to management and design decisions. It was initiated following strategic and political discussions between the Board of Directors and governmental representatives. The aim was to introduce new ideas to improve the organisation's image and the quality of its houses. The board rejected a previous in-house design proposal for CY2, and decided to obtain the design through an architectural competition. This choice was supported by in-house architects and some newly appointed members of the Board with technical backgrounds. The technical department prepared specifications for the architectural competition. The documents included a basic description of the objective of the project and highlighted that it should be characterised by quality in architectural design as well as affordability and social and environmental consciousness. The numerous competitors had to submit a proposed design and a report describing how particular characteristics were considered (including bioclimatic design, energy efficiency and relationship with the immediate and wider environment). There were no explicit requirements or evaluation criteria for environmental performance. Instead, the evaluation committee was responsible for evaluating each proposal's "quality/cost ratio", based on their overall judgement of how well the proposal fulfils the specifications. Two architects mentioned that additional environmental criteria might be introduced in future competitions.

5. How artefacts mediate sustainable design decisions

5.1. Demands and requirements set boundaries to the range of possible design choices

The analysis revealed how various artefacts condition actors' work with sustainable design by directly conveying requirements for energy- or environmental performance. In both countries, various designers and contractors mentioned working with environmental performance only to the extent required by regulations, directives and procurement documents. However, the nature and extent of these requirements differs between the Swedish and Cypriot cases.

In the Cypriot cases, the EU Energy Performance of Buildings Directive (EPBD) was often the only driver mentioned for building design changes related to energy performance:

> *If the EPBD weren't in effect, we wouldn't make any energy performance improvements. […] [Legislation and regulation] radically change the views of stakeholders.*
>
> (CY1 & 2 In-house Architect)

As EU and national regulation provided a background level of performance requirements, the issue of energy performance was taken for granted and was not addressed further in procurement documents for either CY1 or CY2:

> *We didn't really deal with the energy performance of the project in the procurement stage: if it doesn't meet the criteria set by the national regulations, it won't get a building permit.*
>
> (CY2 member of the Board of Directors)

Conversely, both Swedish cases included energy- and environmental performance requirements beside the building code. These were codified through interconnected artefacts originating from various national and local actors. At the local level, energy performance subsidies from the county administrative board motivated the adoption of costly energy performance measures. Owner directives from the municipality defined the environmental ambitions of the MREC:

> *Working with environmental performance means meeting the requirements that we have. The owner, the municipality, has set requirements for the company […] We should be able to report that we meet those requirements. That's my driving force. […] We think we are at a good level where we meet our directives. That's why we are not working with it further. We are complying with the directive when it comes to the environment. So that's enough…*
>
> (SE2 Project Leader)

In the past in Sweden, some municipalities also set overarching requirements for all new construction projects (especially regarding energy performance); however such requirements were forbidden in the Planning and Building Act (SOU 2012:86). The reasoning was that harmonising legal requirements over the entire country would facilitate industrial production of building elements, lead to more efficient and predictable processes and drive down construction costs in a context of high housing demand [4,49]. However, in some cases the municipality preserved these requirements by including them in development plans instead:

> *Previously the municipality had a document called "Better for everyone" […] You are not actually allowed to have this requirement anymore, but they are a bit sly because sometimes they write it in the detailed plans anyway.*
>
> (SE1 Project Leader)

Directives are translated and conveyed through artefacts internal to the MREC, such as the construction handbook at MREC1. In turn, these internal artefacts rely on criteria from national-level tools such as the Miljöbyggnad certification and environmental databases for construction products.

Requirements can therefore ensure a minimum level of attention to sustainable design. However other artefacts may also restrict the range of possible sustainable design options. Affordability requirements can rule out certain options. For instance, the Cypriot NLDA has a requirement to keep production costs and the selling price of the units as low as possible without compromising quality:

> *Materials are more or less predefined, due to financial limitations; we did use the most affordable options.*
>
> (CY1 General Manager - Architect)

The Swedish MRECs also follow requirements including production costs, but also maintenance costs over 10 or 15 years as the dwellings are rented out. Consequently, both MRECs rely on low-maintenance materials, particularly brick facades, despite the fact that brick facades often have a high embodied climate impact [50].

Public procurement law also requires the client to ensure a fair competition and restricts their ability to experiment with sustainable options that are not widely available, especially in traditional contracts. For example in Cyprus:

> *It is difficult to experiment with alternative types of structures, since public procurement procedures specify that products must be widely available to the market's open competition. Due to the small and isolated industry on the island, this was not possible at that time.*
>
> (CY1 General Manager)

However, even in the cases where the association used turnkey contracts or a design competition, none of the bidders suggested an alternative frame type.

Finally, development plans can restrict the use of certain sustainable design options. The architect of CY1 described regional specificities in zoning plans as some of the most important factors determining environmental impact. In Sweden, aesthetic considerations in detailed development plans and local design programs can rule out certain material choices with low environmental impacts:

> *It says in the detailed development plan that the facades should be brick and plaster […] There are usually rules about what the facades should look like, because they should match the other facades.*
>
> (MREC2 Project Leader)

Unrelated requirements can also indirectly block sustainable design choices. For instance, height restrictions in the development plan can prevent construction with wooden frames:

> *In concrete, approximately 260 mm thick floors are built. But in wood, for the same size of building, up to half a meter is needed. So there will be thicker floors. It affects the height of the building. The question is, can we handle it according to limitations in the development plan…?*
>
> (SE1 Architect)

Overall, artefacts conveying formal demands set the boundaries of how the actors' work with sustainable design. On one hand, they restrict the range of possible design options. On the other, they ensure a minimum level of attention to sustainable design within these boundaries.

5.2. Default options simplify the design process

Artefacts also influence actors' work with sustainable design by simplifying design processes, where some complex choices were replaced by default options, or by a simple choice between a few options. One example from Cyprus is the early design of new buildings, which used to be largely based on the direct implementation of standard drawings. While these were seen by some as a limitation to the introduction of alternative designs, the drawings have recently been reworked, and are now adapted to the characteristics of each project. Relatedly, in the early design stage of SE1, the project leader and the sustainability strategist used a checklist of possible sustainability solutions to discuss what sustainable design measures could be relevant for the project. A similar simplification was apparent in later design stages, with decisions over specific choices of materials and construction products. When writing tender documents, the Cypriot NLDA uses an internal database of technical specifications describing materials and technical systems for various building types, somewhat similar to the Swedish MRECs' construction handbook or design directions. These default designs allow project leaders and architects to avoid starting from a blank slate in each new project.

The importance of these default designs and standardised specifications suggests that key sustainable design decisions happen not only within each project, but also outside of the project, when the specifications, guidelines and handbooks are developed or updated. In Cyprus, any NLDA employee can suggest modifications of the technical specifications at any time. If the submission is approved by the management, the change in technical solutions will then be applied in future projects. Project leaders at SE1 and SE2 mentioned that while they do not consider that LCA could be used to steer design decisions within each project, they proposed that it could be used upstream to determine what design solutions are prescribed in the company's guidelines or handbook.

This need for simplification is also apparent in relation to assessments of environmental performance. Multiple interviewees mentioned a willingness to use LCA for this purpose, but only if such tools are quick, easy and user-friendly. In the Swedish cases, environmental databases for construction products outsource the assessment and provide a single-score “sustainability grade”.

The building's environmental performance is therefore to a large extent conditioned by available default options, standardised templates, handbooks and databases. These artefacts simplify decisions and determine what sustainable design options are considered. Such simplified procedures were highlighted as particularly important due to the large amount of complex information that project leaders must handle. Some Swedish interviewees expressed a need for organisational tools and procedures to streamline their work with sustainable design:

> *[Project leaders] have a lot of things to keep in mind, many side documents that they somehow have to remember and keep track of in the right phase. It's overwhelming […] [An appropriate tool] can enable a completely different way of working […] with our different sustainability perspectives, so that we can discuss throughout “what is needed here, at what stage do we need to be reminded of it?”*
>
> (MREC1 Sustainability Strategist)

5.3. Standards and databases influence definitions of sustainable design

Some artefacts influence sustainable design by objectifying this ambiguous concept and influencing how decision makers define it, as well as which aspects of sustainability and design practices they consider. Several examples were particularly noteworthy in the Swedish cases. The first is the reliance on criteria from the widespread Miljöbyggnad certification. Buildings at MREC1 are designed according to the Miljöbyggnad Silver criteria (except for energy use where a separate criterion is used), but MREC1 doesn't usually follow through with the certification process. Hence, even projects that are *not* certified are designed *according to* Miljöbyggnad. At MREC2, the board received a directive asking them to be at the forefront for environmental sustainability, and decided that an appropriate way to fulfil the directive would be to certify all new buildings according to Miljöbyggnad Silver. Ambiguous environmental ambitions in the directive were thus translated into targets indexed on a widespread certification level. This certification policy was later put on hold as it was judged too complex, although MREC2 still applies Miljöbyggnad energy performance criteria.

Because of their wide recognition, the Miljöbyggnad criteria and performance levels have therefore become a de facto definition of environmental sustainability when actors need a concrete and usable reference point, even in cases where the certification itself is not directly used. The Miljöbyggnad certification thus plays a key role in translating the ambiguous concept of sustainability into practical design criteria. The certification is so widespread that it has been internalised, and has become a reference for sustainability criteria and targets even in non-certified projects.

The second example is the MRECs' reliance on environmental impact databases in the selection of construction products. The environmental databases outsource the assessment of environmental performance and provide a single sustainability score for each product. Designers do not assess the environmental performance of construction products, but only look at a product's grade in the database to judge whether it is sustainable or not.

> *As an engineer… I do not go through the product sheets of each product or calculate the carbon dioxide consumption, but I download that data and see “yes, this product is approved”. And then someone else has already done that work for me.*
>
> (SE1 Contractor)

This quote also indicates a misunderstanding of the scope of the database. This practitioner assumes that, by selecting products with a high sustainability score, he is using products with a low climate change impact. However, the scores in the database only cover local environmental- and human toxicity (energy use and climate impact are sometimes reported, but only for information purposes). This simplified and outsourced assessment implicitly determines what aspects of sustainability designers consider or ignore when selecting products. This selection is black-boxed, based on criteria that the users do not question and are not always aware of. Thus, for many designers, the database defines which materials and products are chosen as ‘sustainable’. Only the sustainability strategist at MREC1 opened this black box to help project leaders interpret results from the database in problematic cases.

The Swedish cases show an ecosystem of interconnected and interdependent artefacts acting together to establish the concept of sustainable buildings. The design directions and handbooks at the MRECs require the use of environmental databases. The construction handbook also requires the use of the Miljöbyggnad Silver criteria. The environmental databases include functionalities showing whether a product is compatible with Miljöbyggnad. Many Miljöbyggnad criteria are indexed on the building code. Hence, the notion of what constitutes sustainable building design is strongly reified, codified and enforced through various interconnected artefacts in the Swedish cases, allowing actors to reach a practical common understanding of an otherwise ambiguous concept.

Conversely, in a less codified and regulated arena, the Cypriot cases showed less evidence of artefacts objectifying the concept of sustainable design. The competition specifications for CY2 mentioned the need to consider environmental sustainability and bioclimatic design, but did not include quantified criteria. Proposals were judged based on experts' opinion of their quality in relation to their cost. The views of technical experts seemed to be based on their experience and awareness of sustainable design solutions:

[The tools I use are] my brain, my knowledge, and social sensitivity that comes from a more general perception of the role of the organisation.

(CY1 Civil Engineer)

You do it a bit instinctively. You use your instincts and work with materials depending on the area.

(CY2 Architect)

The level of understanding and concern for sustainability varied widely among practitioners. The perceived viability of a given design solution seems to depend on how widespread it is and on the practitioners' experience with it. In practice, the use of conventional concrete frames and bricks was seen as non-negotiable, partly because practitioners are used to these solutions and have little knowledge of alternatives. Deviating from common practice is only considered if a political decision to do so is taken ahead of the project.

A conventional concrete frame and bricks were used, since it was the standard type of construction commonly used, and a type we had the knowledge for and the know-how.

(CY1 In-house Architect)

Changing the frame type was not negotiable. That was a matter of political decisions as well as knowledge and experience […] It was also a matter of my own experiences and know-how as an architect; I didn't have any experience on working with other materials or designs.

(CY1 Civil Engineer)

5.4. Interplay between artefacts and individual agency

While requirements, default designs, environmental standards and databases influence sustainable design decisions, they do not always do so through straightforward cause-and-effect relationships. Indeed, actors bend, reinterpret and adapt these artefacts on a case-by-case basis. In the Cypriot NLDA, default designs are now adapted to the specificities of each project, and different designers rely on these default options to different degrees. In Sweden, the mandatory use of environmental databases is sometimes departed from and negotiated:

When they can't find any suitable material, they usually check: "can we approve this anyway?" It's about being part of the discussion, and checking alternatives on the market and how much we use this product. Together, you figure out what this deviation means in practical terms.

(MREC1 sustainability Strategist)

Individual actors in the housing organisations also shape artefacts in return. For instance, in the Cypriot NLDA, designers regularly suggest improvements and modifications to the standard typologies. At the NLDA and at MREC1, the development of default designs was driven by one specific manager. Technical managers at MREC2 also claimed to influence the directives they receive:

It is often perhaps based on our input that these owner directives come back. […] We meet municipal clerks in different forums, we take part in different steering groups.

(MREC2 Head of Environment, Quality, Security, IT and Operation)

Therefore, designers retain an important level of agency in sustainable design, and can often reinterpret or modify artefacts. The interplay between artefacts and designers' agency depends on the national context. In Cyprus, policies and plans are generic, leaving much room for the designers' interpretation, with few codified sustainability criteria and requirements. Past improvements in energy performance and a recent initiative to design sustainable communities arose from designers' experience, skills, motivation to improve quality, ability to convince their peers and other situational factors. In Sweden, sustainability targets are more often codified in directives, design guidelines, environmental databases and the Miljöbyggnad certification. However, before these artefacts became so widespread, Swedish designers also relied on experience and interpersonal knowledge transfer:

[The design handbook] did not exist when we wrote the tender specifications. But the ideas have been around for a very long time […] We know what we want when it comes to the technology in our houses.

(SE1 Project Leader)

6. Discussion

6.1. Leveraging artefacts for sustainable design

The original purpose of this study was to identify key factors and decisions influencing environmental sustainability throughout public housing projects in Sweden and Cyprus. The case studies revealed how networks of artefacts support, define and limit actors' work with sustainable design, although these roles differ between the Swedish and Cypriot cases:

- Demands and requirements ensure a minimum level of work with sustainable design, but block the use of certain sustainable design options,
- Default options, predefined templates and guidelines simplify design and limit the number of options considered,
- Standards and databases objectify definitions of sustainability into taken-for-granted criteria and ambition levels.

This has implications for the prioritisation of interventions to promote sustainable design: some important leverage points exist not within the project itself, but upstream, when public authorities, certification bodies or the housing organisation develop these artefacts.

In public housing projects with tight constraints, many actors only engage with sustainable to fulfil mandatory demands in regulations and directives. While previous studies have shown the importance of regulations and demands from the client in driving green procurement [51–54], the present study reveals important differences in the respective roles of authorities in Sweden and Cyprus. In Cyprus, planning is broadly determined at the national level. Practitioners focus on fulfilling governmental directives and requirements from national and EU regulations, with many opportunities for ad-hoc decisions and judgement calls. Conversely, in Sweden, both national and local authorities steer sustainable design at a distance through ecosystems of interdependent artefacts [4,27]. In particular, municipalities considerably influence sustainability ambitions by setting directives for the MRECs, which are translated into internal objectives and design guidelines. Many of these guidelines rely on the Miljöbyggnad certification and environmental databases, indicating that Sweden Green Building Council (who manages Miljöbyggnad) and private companies maintaining these environmental databases have a responsibility in shaping the content of sustainability requirements. Furthermore, the study exemplified how unrelated requirements might inadvertently block certain sustainable design options. For instance, aesthetic guidelines enforced the use of brick facades, height limits in development plans could hinder the use of timber frames, and public procurement laws prevented experimentation with niche solutions, especially in Cyprus.

Managing complexity within the project is a key issue for the uptake of sustainable design, as there is little room to assess sustainability within the project itself. One pathway to overcome this barrier has been to simplify such assessments and integrate them with existing tools, e.g. with the integration of LCA to building information models (BIM) [55,56]. Another pathway is instead to leverage the use of default options within the housing company. The present study showed how design guidelines, checklists and databases determine what sustainable design solutions actors consider. These standardised options are essential for actors to streamline complex design processes, and could provide a medium to build up knowledge of sustainable design solutions within the organisation [26,28]. Efforts to promote sustainable design should arguably focus not only on individual projects, but also on how standardised options are created and updated within the organisation. Individual managers played a key role in shaping these artefacts in both Swedish and Cypriot cases. In the Cypriot cases, all employees could propose updates to these typologies, which offers a systematic way of accumulating knowledge.

However, while requirements and default solutions offer entry points for sustainable design within the organisation, they do not determine sustainable design decisions through rigid cause-and-effect relationships. These decisions result from an interplay between human actors and networks of artefacts [17,57]. Design guidelines can draw attention to sustainable design options, but they are sometimes departed from or adapted on a case-by-case basis. When practitioners struggle to fulfil sustainability requirements (such as finding products with an acceptable grade in environmental databases), these requirements become instead a basis for negotiation. Thus, environmental performance depends on the ability of individual practitioners to adapt guidelines and requirements to each use case. Notably, at MREC1, a "sustainability strategist" assisted project leaders with the qualitative judgements and ad hoc tinkering required in the practical implementation of sustainability standards and assessment tools [34,35,38]. In Sweden, sustainability criteria have been increasingly codified into networks of interconnected artefacts in recent years, but the experience and judgement of designers still carry an important weight [30]. In Cyprus, the experience, motivation and skills of individual actors, in particular managers and architects, appeared even more crucial for the adoption of sustainable design.

Finally, in the Swedish cases, there is evidence of a more complex role of the Miljöbyggnad certification and environmental databases for construction products. These artefacts influence actors' understanding of the ambiguous notion of sustainability, operationalising it through actionable practical criteria and agreed-upon target levels. They play a key role in translating and giving meaning to this abstract concept not just within the project, but in the entire organisation [15]. Studies of standardisation have shown that compliance with standards can be critical to obtain legitimacy and approval [12,33,34,37]. Our study found effects that extend beyond formal compliance: Miljöbyggnad criteria and target levels have been internalised by actors as de facto definitions of sustainability, and are used even when the building is not certified.

By providing this shared language and reference points, the Miljöbyggnad certification and environmental databases play important roles as boundary objects [16,38], through which designers can reach a practical common understanding of sustainable design, enabling cooperation. This draws attention to the organisational features of sustainable design tools [12,37]: their value lies not only in *what* they prescribe, but in *how* they raise awareness and facilitate actors' work with sustainability. Miljöbyggnad and environmental databases also act as black boxes: by rendering only certain aspects of sustainability calculable, they determine what issues are addressed or silenced based on criteria that are rarely examined [12,35]. Black-boxed tools are necessary to simplify actors' work, elicit action by creating consensus, and provide reliable and legitimate references [27,30,35]. However, these tools were not designed with the purpose of becoming universal definitions of building sustainability. Questions regarding what aspects of sustainability are silenced, and what ambition levels are appropriate, becomes particularly relevant when these standards move from opt-in tools to de facto definitions. In particular, Miljöbyggnad Silver and environmental databases do not currently require the selection of materials with a low climate impact. The recent introduction of a mandatory declaration of embodied climate impact for new buildings in Sweden can be seen as an attempt to integrate a climate dimension in the common definition of building sustainability.

6.2. Limitations

A caveat to the study's internal validity is that the Swedish and Cypriot case studies were carried out by different researchers. While both researchers participated in analysing all transcripts, their different perspectives likely coloured how they carried out the interviews. Notably, the researcher carrying out the Cypriot case studies is a former employee of the Cypriot NLDA. Furthermore, interviews had to be carried out remotely due the Covid-19 pandemic and time constraints, Although we have highlighted the practical implementation of artefacts by practitioners as a crucial aspect, we were not able to directly observe how actors interact with artefacts.

The exploratory and inductive design of the study helped highlight interesting and surprising aspects of the cases. Notably, it directed attention to the role of artefacts in shaping sustainable design as we realised how much the projects studied relied on standardised solutions. It also underscored differences between national contexts, as it became clear that Swedish designers based their work with sustainable design on multiple interconnected artefacts, while Cypriot designers relied much more on their experience. Both aspects are important takeaways for the implementation of sustainable design tools such as LCA.

However, this approach to data gathering and analysis also limited the study's external validity and ability to provide far-reaching conclusions. It does not enable us to test a hypothesis or to rigorously isolate the effects of a particular artefact [58]. In particular, we could not reliably identify success factors for the implementation of sustainable design tools.

Furthermore, generalising findings requires attending to the particularities of place-based contexts and engaging with local differences [59]. Indeed, our transnational comparison shows that artefacts play very different roles in different national contexts. Generalising results to other countries calls for an understanding of each national context in relation to planning and construction, and whether these rely more on systems of codified requirements or ad-hoc decisions [45]. Finally, the effects identified might depend on the type of project. Default options, budgets and directives likely play a stronger role in public housing projects compared to other types of projects, since public housing is characterised by more standardised forms and tight constraints. While we have highlighted the development of default designs as a key entry point where appropriate tools could support sustainable design, this finding might be less relevant for less standardised projects (in particular large flagship projects).

7. Conclusion

This study has illustrated how artefacts influence sustainable design practices in public housing projects in Sweden and Cyprus, by:

- Setting boundaries to the range of available options through formal demands and requirements,
- Simplifying design choices through default options, templates and guidelines, and
- Influencing how designers understand sustainability through definitions codified in widespread standards and tools.

While other studies have considered the roles of artefacts in building design, the present study's novelty lies in its purpose-driven analysis of their effect on sustainability, its focus on public housing, and its transnational comparison of cases in Sweden and Cyprus.

The findings help identify leverage points to promote sustainable design. First, requirements and directives are major drivers of sustainable design choices, especially in projects with tight budget- and time limitations. However, the extent of sustainability requirements and actors responsible for their introduction depend on the national context. In Sweden, national and local authorities set detailed and codified demands, whereas in Cyprus more freedom and responsibility is given to individual designers, and sustainable design depends on their skills and motivation.

Moreover, the study highlights how default solutions and internal guidelines within the organisation influence what sustainable design options practitioners consider. This has important implications for the use of decision support tools such as LCA. In projects with tight budgets and high degrees of standardisation, streamlined procedures are needed and LCA is unlikely to be cost effective. Instead, LCA could be implemented at the level of the organisation, during the development and revision of these default options and guidelines.

Furthermore, the study draws attention to the organisational features of sustainability assessment tools, databases and standards, especially in Sweden. By providing consensual and actionable references for what it means for a building to be sustainable, they translate the ambiguous concept of sustainability into practical criteria and enable cooperation. The potential of such tools to improve environmental performance lies not only in their content, but in *how* they integrate with existing practices, put sustainability on the agenda, and facilitate actors' work with sustainable design.

However, these tools, databases and standards often constitute “black boxes” that highlight certain aspects of sustainability by rendering them calculable, and silence others. There is a risk that important aspects of sustainability are left off the agenda, or that relevant solutions are disregarded because their benefits cannot be easily calculated. Designers and users of sustainability standards such as Miljöbyggnad should be aware of what aspects of sustainability they highlight or silence and whether they set appropriate target levels, especially when they become de facto definitions of sustainability.

Finally, the transnational comparison of cases draws attention to the different roles played by artefacts in different national settings. As policies and initiatives to promote sustainable design are becoming increasingly harmonised in the EU, this calls for an awareness of their local context of implementation. Demands, default options and definitions of sustainability codified in artefacts all influence sustainable design and offer leverage points to promote it, but their effects depend on the ways they interact with the practices of local actors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix 1. Semi-structured interview template

The interviews were loosely based on the following template, allowing for departures from this structure and follow-up questions.

A. Personal details
   Name, age, educational and professional background, current position and years of experience.
   General information regarding the organisation
B. Organisational structure
   How does a project start? How is the decision to start a project taken? What is the context of those decisions?
   Does the organisation follow particular objectives, requirements, internal standards, guidelines, etc.?
   Who is responsible for design decisions? Who makes suggestions and proposals regarding the design, and who takes the final decision?
   Who makes suggestions and proposals regarding the environmental performance of the project, and who takes the final decision?
C. Personal perspectives
   How would you define a green building? A building with high environmental performance? A low carbon building? A low embodied carbon building?
   Which decisions do you think have the most significant influence on the building's environmental impact? When and by whom are they taken?
   When do you think decisions regarding a project's environmental performance should be taken? What happens in practice?
   Who do you think are the most influential decision makers and why? Who is driving work with sustainability in the organisation?
   What factors influence the design team's decisions regarding environmental impacts? Who or what are the main drivers towards including environmental aspects in the design?
D. Project specific/decision making
   How are decisions usually taken during the project?
   How are environmental impacts evaluated? How are embodied carbon and energy considered, explicitly and implicitly, during the design and construction of buildings? What decisions are taken to reduce them? What weight do these sustainability criteria have in influencing design decisions?
   Can you mention some decisions taken during the project, which had an impact on the environmental performance of the project? What were the main factors that led to the adoption of those decisions?
   What drivers led to improvements of the environmental performance of the project?
   How do legislation and regulations influence stakeholders in the building project?
E. Tools and methods
   What kind of tools did you use during the design of the project? What tools did you use to support decision making?
   Which tools do you use to evaluate environmental performance?
   How much do you know about life cycle assessment (LCA)? Have you ever used LCA tools?

How much do you know about Sustainability Assessment Tools such as BREEAM, LEED etc.? Have you ever used such tools?
Would you consider using LCA to assess environmental performance in design and inform design decisions? Why or why not? What would be your requirements in order to use an LCA tool in design practice? Would prefer using other tools such as checklists?
What do you think are drivers and challenges to the use of environmental performance assessment tools in the building sector?

Appendix 2. Interview participants

Case	Participants interviewed
Both Cypriot cases	Deputy general manager of the national land development association (NLDA)
	In-house architect
	Sales manager of the NLDA
	Technician
	Five members of the Board of Directors of the NLDA (two engineers, two managers and one architect)
Cypriot case CY1	Two civil engineers
	Mechanical engineer
	General manager of the NLDA
	Two technicians
	Engineer from the Board of Directors
Cypriot case CY2	Three architects who participated in the design competition
Swedish case SE1	Project leader
	Architect
	Contractor engineer
	Head of construction in the executive group
	Sustainability strategist
Swedish case SE2	Project leader
	Architect
	Consultant construction manager
	Contractor site manager
	Contractor representative
	Two members of the executive group (head of construction and development and head of environment, quality, security, IT and operation)

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