Adaptability Consultant: A Support Tool to Evaluate Building Adaptability in the Housing Sector

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# Adaptability Consultant: A Support Tool to Evaluate Building Adaptability in the Housing Sector

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**Abstract**

In response to persistent global challenges in the affordable housing sector—including low building quality, affordability, and sustainability—this research identifies building adaptability or design for adaptability (DfA) as a potential strategy. An Excel-based assessment tool using a weighted-sum methodology is developed to support both the design and evaluation of adaptable buildings by quantifying their adaptive capacity across new constructions, refurbishments, and existing buildings. The tool is refined and validated through expert elicitation, including 14 survey responses and 8 semi-structured interviews. The expert feedback contributed to improving the tool and also indicates a high degree of acceptance among scholars. Subsequently, three case studies of well-known adaptable residential buildings are analysed to assess the tool's applicability and the consistency of its results. The case-study results further reveal that buildings commonly perceived as adaptable do not necessarily exhibit adaptability in a comprehensive, multi-dimensional manner. The case-study analysis also revealed substantial variation across adaptability types (e.g., from 0.19 to 0.67 for Adjustability), demonstrating the value of a multi-dimensional assessment. It also revealed how adaptability priorities vary following localized context analysis (e.g., the required threshold for Movability decreased from 0.50 to 0.10). The tool might support academics, designers, and technical professionals—during both early design and detailed design phases—in evaluating how design decisions influence a building's capacity to accommodate change over its lifecycle. In addition, it provides guidance for policymakers and project owners in defining future-proof project requirements. Areas of future research include expanding the sample size of buildings to produce statistical data, tailoring the tool for different building typologies, statistically validating qualitative default values, and verifying design actions derived from academic literature and case studies.

**Keywords:** assessment tool; evaluation method; design for adaptability; building adaptability; adaptive capacity; affordable and social housing

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## 1. Introduction

*The Case for Building Adaptability in Affordable Housing*

UN-Habitat estimates a global housing shortage affecting approximately 3 billion people by 2030 [1], driving an increase in the demand for buildings and infrastructure.

Current approaches to affordable housing development often prioritise low upfront costs, frequently at the expense of long-term affordability [2], construction quality [3,4] and sustainability [5], undermining Sustainable Development Goal (SDG) 1.1 and related sustainability goals.

Within this context, a long-term sustainability perspective becomes imperative. One of the most significant barriers to achieving Sustainable Affordable Housing (SAH) is, in fact, ensuring that projects remain sustainable, affordable, and effective over time [6].

However, many affordable housing developments lack the capacity to adapt to internal and external changes. Buildings that fail to meet—or cannot be easily adapted to—evolving needs often experience reduced performance and quality or higher lifecycle costs, energy consumption, early obsolescence, disrepair, health risks, vacancy, informal interventions, major refurbishments and demolition [7].

In the EU, for instance, 11% of buildings undergo some form of renovation each year. Around 0.2% of the stock experiences 'deep' renovation, while achieving climate neutrality by 2050 would require this annual rate to increase to approximately 3% [8].

Building adaptability—broadly defined as the "ability to be changed or modified to make suitable for a particular purpose" [9] or as "the capacity of a building to accommodate effectively the evolving demands of its context, thus maximizing value through life" [10]—has been recognised as a critical factor in the assessment of sustainable housing programs [11] and as an effective strategy for achieving sustainable affordable housing [12].

The literature identifies multiple benefits associated with adaptable buildings, including improved change efficiency, reduced lifecycle costs, improved investment value, enabled stability and transformation, improved operational efficiency, improved user satisfaction and inclusivity, increased building longevity, and reduced environmental lifecycle impacts [13].

When applied to affordable housing projects, adaptability improves housing adequacy by supporting affordability, potentially reducing operational and refurbishment costs; habitability, mitigating overcrowding through internal flexibility and improving structural robustness and indoor environmental quality; and accessibility, facilitating age-friendly design and accommodating emerging disabilities. Moreover, adaptability fosters cultural adequacy by favouring adaptations in response to user preferences, supports climate-change mitigation and adaptation through improved thermal comfort and reduced energy consumption, and provides informality control by establishing a framework for future transformation during the design stage [7].

Empirical evidence from built case studies of the 20th century suggests both the feasibility and acceptability of building adaptability. Notable examples include *open-plan* floor layouts, *open-building* principles, and *incremental housing* approaches. However, the existing literature reveals significant limitations. Building adaptability is often addressed in a fragmented manner, lacking a comprehensive and systematic framework. Design guidelines, performance requirements, and operational tools to support academics and practitioners remain scarce. Likewise, assessment methods to evaluate the adaptability of projects are limited, undermining the practical operability of the concept and representing a significant challenge [14]. In professional practice, adaptability is typically implemented through isolated case studies or sporadic design actions, while empirical evidence is still insufficient.

Nevertheless, adaptability strategies involve trade-offs that must be carefully managed. For instance, increased structural capacity, oversized building services, or greater floor-to-ceiling heights may raise upfront costs and embodied environmental impacts, highlighting the need for balanced, context-sensitive design decisions [15]. Today, a transformed context renders adaptability increasingly essential. Advances in dry construction technologies, the need to reduce environmental impacts, shifting social expectations like demographic changes, and government incentives create a context in which adaptable buildings support long-term sustainability and affordability.

According to the exposed research context, this study is based on several propositions. First, building adaptability has a critical role in long-term housing sustainability and affordability, as it reduces the need for major refurbishments and prevents premature demolition. Furthermore, a context-sensitive assessment tool enables a meaningful evaluation and adoption of building adaptability. Adaptability is inherently multi-dimensional, encompassing multiple typologies and building layers, and therefore requires an assessment approach capable of capturing this complexity. In addition, weighted indices provide a more comprehensive representation of adaptive capacity than single-criterion or unweighted approaches, as they reflect the relative importance of different factors. Finally, the involvement of experts is essential for refining the tool and enhancing its academic acceptance.

These propositions converge on a central research question: how can building adaptability in the housing sector be systematically assessed through a context-sensitive, multi-dimensional evaluation approach?

This research aims to enable the comprehensive implementation of building adaptability in affordable housing by developing a methodology for evaluating adaptive capacity, embedded within a tested design-support tool for designers and developers. The tool helps to identify design actions in housing developments, facilitates the evaluation of trade-offs, and enables the evaluation of the adaptive capacity of the existing stock for benchmarking purposes. While the primary focus is on residential buildings, the proposed methodology might be customised to other types of buildings and interventions.

## 2. State of the Art

### *2.1. Adaptability Regulations, Standards, and Rating Systems*

Across research agendas, public policies, and professional practice, there is growing recognition that long-term sustainability requires future-oriented design [16,17] and building adaptability is increasingly promoted.

Design for adaptability, re-use and deconstruction of buildings, in line with the principles of circular economy, are at the centre of European research programs like Horizon Europe [18]. This emphasis is evident in the 2025 "New European Bauhaus Facility" program, financed by Horizon Europe, in the 'Business-01' call on 'Renovating the built environment through design for adaptability and disassembly'. A strong focus on climate adaptability is also reflected in other programme calls and reinforced by recent regulatory developments, including the new Energy Performance of Buildings Directive (EPBD), which highlights the need for buildings to be able to adapt to changing climate conditions [19]. Building adaptability is also evident at the government level, as highlighted, for example, in the UK Government's Strategy for Sustainable Construction [20] and within multiple national regulations and international standards. This growing emphasis is primarily driven by the need to adapt to evolving social and environmental conditions (such as emerging disabilities and climate change).

Regulations typically establish mandatory requirements for adaptability, while standards provide non-binding guidance that often informs regulation.

Many national regulations and standards prioritise universal design principles [21], aiming to create accessible and inclusive environments, by providing requirements for dwelling access, door and corridor widths, and minimum room sizes, among others. Examples include: the USA Fair Housing Amendments Act [22]; Australian Standard 4299-1995 [23]; the Australian Livable housing design guidelines [24]; the UK Lifetimes homes standard [25]; Building Regulations Part M [26]; Norwegian building construction standard TEK 17 [27]; and other regulations in countries such as the Netherlands, Scandinavian countries, New Zealand and Italy. Additional regulatory frameworks address adaptability in relation to specific hazards, including earthquakes, flooding, and fire.

However, comprehensive government measures addressing future changes and stresses remain limited. One notable example is Japan's Technical Guidelines for the Longer Life of Housing (a certification system based on a law, 'the Act on the Promotion of Dissemination of Long-life Quality Housing'), which also guarantees fiscal incentives [28]. These guidelines aim to prolong the lifespan of buildings by addressing durability, earthquake resistance, ease of maintenance and renewal, adaptability, universal design, energy efficiency and conservation, adequate floor area, maintenance of the living environment, and long-term maintenance planning [29].

In parallel, international standards provide more detailed technical specifications and design strategies for adaptable design, offering guidance on elements such as flexible layouts, structural capacity and service integration.

ISO 20887:2020 [9] addresses adaptability alongside disassembly and durability and provides qualitative and quantitative measurement guidelines for versatility, convertibility, expandability, ease of access to components and services, independence, reversible connections, avoidance of unnecessary treatments and finishes, support for re-use business models, simplicity, standardization, safety of disassembly, and durability. EN 17680:2023 identifies adaptability as a core criterion in evaluating sustainable refurbishment. In particular, its Annex 3 provides examples of criteria for adaptability performance and performance classes. The Level(s) framework [30], which includes an indicator focused on building adaptability, provides evaluation for office and residential buildings. With respect to residential buildings, for example, the framework includes evaluation of changes to the internal space distribution, building services, the use of units or floors, and access requirements.

Building rating systems increasingly incorporate adaptability and related concepts as evaluation criteria for sustainability certification. For example, the BREEAM indicator titled 'Design for disassembly and adaptability' [31] provides qualitative prescriptions, considering feasibility, accessibility, versatility, adaptability, convertibility, expandability, refurbishment potential, durability, exposed and reversible connections, layer independence, avoidance of unnecessary toxic treatments and finishes, and standardisation. The LEED indicator titled 'Design for Flexibility' [32], applied to healthcare buildings, provides qualitative and quantitative requirements contributing towards credit. It provides a list of potential strategies, including the use of interstitial space, providing programmed soft space, providing shell space, identifying horizontal expansion capacity, designing for future vertical expansion, designating space for future above-grade parking structures, using demountable partitions, and using movable or modular casework. The DGNB indicator titled 'Flexibility and adaptability' [33] employs a point-based credit system, assessing various criteria, each accompanied by specific requirements depending on the building typology. It provides a list of requirements—namely, space efficiency, multi-use of areas, ceiling height, building depth, vertical access, floor layout, structure and technical building services. The Adaptive Capacity of buildings [34,35] was developed by the Dutch Government, along with a number of companies and branches of the construction industry, for measurement of the potential for building adaptation. It is a scoring system to evaluate the Adaptive Capacity of buildings, with points given based on four classes of building requirements. Similarly, the TOE1, within the Belgian GRO 2022 rating system [36], evaluates circular and future-oriented design assessing a series of questions related to the physical characteristics of the building and ultimately generates a final score.

However, despite the promotion of instruments, specific actions and requirements for different adaptability types are not clearly defined.

### 2.2. Evaluation Methods in the Academic Literature

Beyond the regulations, standards and rating systems discussed in Section 2.1, a range of academic evaluation methods has been developed to assess building adaptability [37] (Table 1) at all stages [38]. The literature compares multiple adaptability evaluation methods [13,37,39–43], which can generally be grouped into three categories. The first consists of models that aid in the initial design of new buildings (or deep renovations). The second includes models that assist in deciding between end-of-life options (adaptation, demolition or nothing). The third comprises models that aim to capture the entire life of a building as it moves through the obsolescence–adaptation–relevance cycle [40]. Others categorize them as model-based, multi-criteria and scenario-bound methods [44].

**Table 1.** Assessment tools for adaptability evaluation.

| Name | Brief Description | Evaluation Method | F. | V. | S. |
|---|---|---|---|---|---|
| Adaptive Reuse Potential (ARP) | A scoring system that evaluates, through formulas, the obsolescence of building parts in relation to the useful life of a building. | Calculation of ARP score and graph. | P, C | Y | 2. |
| Adaptable Building Design (ABD) framework | A predictive framework (for the relevance–obsolescence–adaptation cycle) that examines the financial feasibility of adaptability (options) of a building in light of future uncertainties such as market conditions | Predictive framework (economic valuation) | P, C | N | 3. |
| IconCUR | A conceptual framework to assess building obsolescence to understand the potential adaptability of a building. | Decision-making (weighted) matrix | P, C | Y | 2. |
| AdaptSTAR | A star-based weighted-checklist scoring system based on 26 criteria and 7 categories of obsolescence, considering both building-related and context-related factors. | Ranking values (star-rating) in a checklist (algorithm) | P, C | Y | 1. |
| Causal Loop Diagram (CLD) of building adaptation | A graphical model representing the different variables and their relations in a system to describe building adaptation. | Causal loop diagram (conceptual model) | P, C | N | 3. |
| Preliminary Assessment Adaptation Model (PAAM) | A flowchart with quantitative assessments (point-based) to determine if adaptation is feasible. The assessments are based on a principal component analysis that identified 12 attributes of buildings highly correlated with adaptation projects. | Decision-making flowchart (point-based) | P, C | Y | 2. |
| Flex 4.0 | A point-based system to sort buildings into different classes of adaptability (from no adaptability to excellent). A set of indicators considers both building-related and context-related factors. Points are calculated based on building physical features. | Ranking values in a checklist (flexibility score) | P | Y | 1. |
| Adaptive Capacity of buildings [34,35] | A scoring system to evaluate the Adaptive Capacity of buildings. Points are given based on four classes of building requirements. | Ranking values in a checklist | P | NA | 1. |
| Triple-bottom-line retrofit optimization | A series of scans with increasingly complex assessments similar to the 'conversion meter'. Criteria include physical and context features; energy usage and greenhouse gas emissions are given particular attention in the methodology. | Ranking values in a checklist | P, C | Y | 2. |

**Table 1.** *Cont.*

| Name | Brief Description | Evaluation Method | F. | V. | S. |
|---|---|---|---|---|---|
| Learning Building Framework (LBF) | A guide (quantitative framework) for designing adaptable buildings. An adaptability score is determined for each building layer according to the presence of adaptability enablers and the relative criticality of the layers. Prior Analysis, a theory used for risk assessment, is applied to calculate the degree of presence factors (probability and impact). | Calculation of adaptability score | P | N | 1. |
| Conversion meter | It consists of a series of 4 checklists containing binary yes/no questions to evaluate the adaptive potential of buildings. One feasibility scan is based on the physical features of the building. The number of 'yes' answers is summed and multiplied by a weighting. | Ranking values in a checklist | P, C | Y | 2. |
| Transformation Capacity Tool (TCT) | A set of rules to assess building adaptability based on building-related factors. | NA | P, C | Y | 3. |
| Spatial Assessment of Generality and Adaptability (SAGA) | A method to compare the adaptability of different spatial layouts by evaluating generality and adaptability based on space permeability and partition technologies. | Calculations and spatial analysis | P | Y | 3. |
| Adaptive Reuse Assessment Model (ARAM) | A qualitative flowchart considering economic, technical, legal and physical aspects, focusing on the adaptive reuse and adaptation potential of heritage buildings. | Decision-making flowchart | P, C | Y | 2. |
| Dependency Structure Matrix (DSM) | A quadratic NxN dependency structure matrix that determines the relationships among the items. | Matrix identifying relations among items | P | NA | 1. |
| Analytical Hierarchy Process (AHP) Model | A multi-criteria decision-making (MCDM) approach to define the most appropriate among multiple alternatives for building conversion. | Decision-making model | P, C | Y | 2. |
| Areal Openness Model (AOM) | It provides three different aperture indicators used to evaluate the adaptive potential of a building. | Calculation of indicators | NA | NA | NA |
| Financial and LCA analysis [45] | It adopts a comparative financial, LCA and social analysis of open-plan design (built-in) adaptability and conventional (non-built-in) adaptability. | Cost, LCA and social analysis | P | Y | 3. |
| Andrade and Bragança (2019) | A tool for evaluating designs by scoring the design on multiple flexibility criteria, then aggregating the scores using the weighted-sum method. | Calculation of adaptability score (weighted sum approach) | P | NA | 1. |
| Da Fonseca et al. (2019) | A tool for rating flexibility and adaptability. The tool helps decision-makers choose building components (scoring 10 parameters) that offer the greatest flexibility and adaptability. | Calculation of adaptability score (weighted sum approach) | P | NA | 1. |

**Table 1.** *Cont.*

| Name | Brief Description | Evaluation Method | F. | V. | S. |
|---|---|---|---|---|---|
| Al-Jameel, Al-Hafith [46] | It presents three indicators to measure design characteristics that affect building adaptability (Structure Modularity, Structure Concentration and Zoning Areas of Special Provision). | Calculation of indicators | P | Y | 1. |
| New Transformation Meter, Geraedts and de Vrij's (2014) [35] | It proposes three instruments (quick scan, feasibility meter and checklist) to evaluate the feasibility of building conversion. | Mixed methods | P, C | NA | 2. |

Sources: [13,37,39–43,47,48] S. = Stage—1, Applied before building construction; 2, applied before building renovation; 3, building life cycle. V. = Validation—Y = Yes; N = No.; NA = Not Acquired.; F = Features considered; P = Physical; C = Context.

Most reviewed models consider both contextual (such as economic, legal, social and political) and physical (such as physical, functional and technological) features influencing a building's adaptability [39,40]; however, these aspects often overlap without clear distinction. Notably, no tool explicitly considers environmental aspects such as climate change.

Many of these tools adopt Brand's building layer categorization [48], which enables adaptability to be addressed at different building levels and is therefore a widely recommended framework [49].

A common methodological approach is the use of weighted-sum scoring across different criteria [37]; however, alternative methods such as ranking checklists, indicator-based assessments, or theoretical/methodological guideline frameworks are also employed. While these approaches may oversimplify complex trade-offs, they remain easy to apply. Conversely, more advanced methods—such as AHP, DSM, or CLD—attempt to model interdependencies and decision hierarchies yet are less frequently adopted in practice due to their inherent complexity.

Additionally, several tools analyse obsolescence criteria in their methodologies as a trigger for adaptive reuse and evaluate the potential of existing buildings for reuse (e.g., ARP, ABD, IconCUR, AdaptSTAR, PAAM and ARAM) [39,47]. Many also apply ordinal scales—typically four values—to evaluate design 'actions', as seen in Lamounier and Flex 4.0., or Level(s), TOE1 GRO, Adaptive Capacity of buildings, EN 17680:2023, and other research [50]. Other approaches consider quantitative evaluations of cost, lifespan, execution time, system compatibility (measured by their modularity and connectivity), execution complexity, modification and reuse potential [48].

Overall, as highlighted in Table 1, criteria and indicators in the reviewed tools are predominantly qualitative and/or qualitatively quantified by nature [47] and rely heavily on expert judgment, with limited efforts to quantify their sustainability [45]. Therefore, existing adaptability evaluation techniques frequently lack objective, quantifiable methods, and they offer limited insight into strategies for enhancing adaptability, representing a theoretical guideline for experts. By contrast, physical and spatial parameters, such as storey height and plan depth, offer more actionable design guidance [14].

In summary, building adaptability lacks methods that quantify a building's capacity to adapt as well as empirical data that prioritize valuable criteria facilitating adaptations [47]. Existing methods frequently overlook context-specific evaluations and fail to provide clear actions to increase Adaptive Capacity in a comprehensive way, especially in relation to different adaptability types and motives for change.

Another critical limitation highlighted by Table 1 is the lack of explicit treatment of uncertainty. While adaptability inherently relates to uncertain future conditions, very few methods (e.g., ABD) incorporate probabilistic or scenario-based approaches.

Moreover, only a limited number of frameworks explicitly consider the specific requirements of residential adaptability (e.g., TCT and SAGA), mostly without targeting a specific building type or focusing on commercial and office buildings [47].

For the purposes of this study, Table 1 highlights three main gaps with respect to adaptability tools for housing: (i) limited quantification of building adaptability, (ii) weak integration of context-specific and environmental drivers, and (iii) insufficient linkage between evaluation outputs and design actions.

### *2.3. Theoretical Framework for Tool Development*

The theoretical framework discussed in this Section informed the development of the evaluation tool.

Briefly, this considers: (i) the analysis and adoption of drivers and trends of change to identify relevant risks and their associated building changes, (ii) drivers are mapped in relation to adaptability types according to Schmidt's classification, (iii) adaptability types associated with corresponding design strategies and actions and (iv) building layers following Brand's model. Finally, the presence of design actions is translated into measurable parameters and evaluation criteria (see Section 3.3).

#### 2.3.1. Drivers and Trends of Change

Design for adaptability involves preparing for the key changes and challenges that structures may encounter throughout their lifecycles, thereby reducing the impact of renovations or demolitions.

Consequently, change factors, referred to as drivers, must be identified, analysed, and integrated within the design workflow.

These drivers are forces determining adaptations in urban and building environments, potentially transforming a system into observable trends [51] that should inform the way we design. Drivers may be global or local, as well as internal or external, and give rise to observable trends that reflect existing patterns evident in society and emerging from existing issues (the drivers) [52].

The analysis of drivers and associated trends from the scientific literature reveals a multifaceted landscape of factors shaping the need for adaptability of buildings and urban design. Drivers and trend analysis are frequently adopted as foresight methods to identify influential forces of change, thereby enabling future-proofing, understood as the capacity to protect and secure to the unknown future. Potential drivers and trends of change are categorised using the STEEP framework (the Social, Technological, Ecological/Environmental, Economic, and Political/legal dimensions) (Figure 1, Appendix A Table A1).

Their understanding facilitates an examination of a spectrum of probable and plausible futures to accommodate uncertainty [53]. This approach acknowledges that future-proofing must consider for the implications of climate change, resource scarcity, demographic shifts, socio-cultural transformations, technological advancements, and evolving regulatory frameworks [54], among other factors. Key topics in relation to factors of change in new and refurbished buildings are the issues of indoor environmental quality, adaptation to climate change, fire safety, risks related to intense seismic activity, the removal of hazardous substances and the accessibility for persons with disabilities [19].

Drivers can be understood as external or internal events that generate observable effects on buildings and their performance, manifesting as trends of change. Such drivers may be conceptualised as risks and may be associated with a range of probability of occurrence and severity of impacts, as defined in risk assessment theory [55], an approach also considered in the LBF method [40]. Although many identified drivers are social, internal to the building, and local in scale, external forces such as environmental hazards, resource availability, and regulatory frameworks are important due to the potential severity of their impacts.

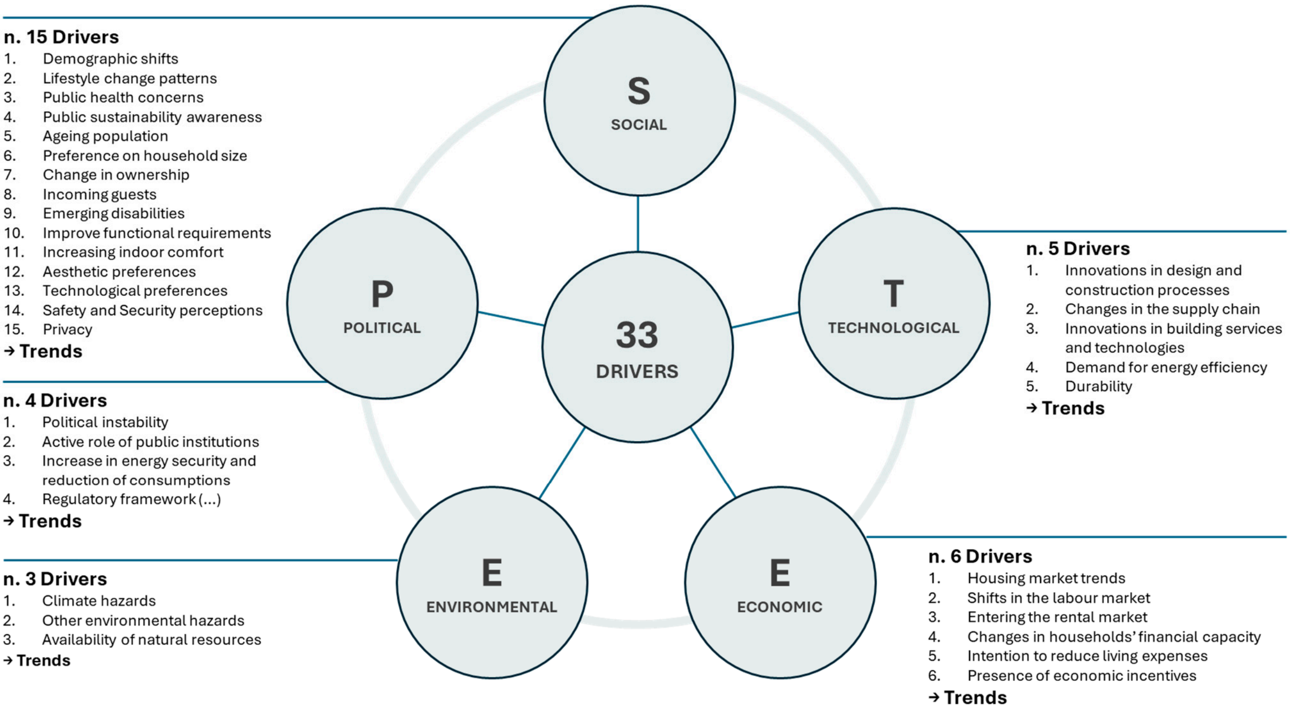



**Figure 1.** Drivers of change. Authors' elaboration of drivers of change (factors determining changes in residential buildings).

Further quantitative research on drivers through risk assessment might provide a robust framework for mitigating uncertain future conditions and enhancing building resilience.

Prioritising adaptability therefore requires identification of drivers with high probabilities and impacts and the design or management of buildings to remain functional under the most plausible risk scenarios.

Although the comprehensive set of trends of change, derived from the same literature as the drivers, is included in the proposed tool, they are omitted from this article for brevity.

Social factors, such as demographic shifts and lifestyle patterns, emerge most frequently, giving rise to trends including, among others, shrinking or enlarging housing units, reconfiguration of layout plans, replacement of services and finishes, etc.

Technological and environmental drivers are also central, with trends such as innovations in design and construction techniques, building services, technical performance, etc., intersecting with the potential effects of climate hazards and resource availability, thereby promoting the use of new technologies or their simple replacement, as well as the integration of smart systems and energy efficiency measures.

Economic drivers, ranging from shifts in household financial capacity to broader housing-market dynamics, highlight pressures that manifest in refurbishments, reduced maintenance, changing ownership patterns, the adoption of energy-efficient retrofits, etc.

Political (legal and institutional) factors such as regulatory frameworks, policy incentives and stability further shape these transformations by enabling or constraining adaptive responses (Appendix A Table A1).

### 2.3.2. Key Frameworks: Adaptability Types and Building Layers

Drivers of change may trigger physical changes to buildings, which can be executed by involving different stakeholders: end-users, owners, professionals, manufacturers and policymakers. According to Schmidt [56], these changes can be categorized into six main change types: task-level changes (or adjustments to individual building elements, such as doors, windows, or finishes), space-level changes (or modifications to the layout or spatial configuration, such as partitioning or combination of rooms), performance-level changes (or enhancements to building performance, such as improved energy efficiency or noise insulation), function-level changes (or alterations to accommodate new uses or user activities, such as adding a home office or gym), size-level changes (or expansions or reductions in the building's footprint or internal volume) and location-level changes (or relocation of building units through disassembly and re-construction). These change types can be enabled through different types of adaptability strategies: adjustable, versatile, Refitable, convertible, scalable and movable [56].

Other analysed classification frameworks are considered less comprehensive or consistent and propose different classifications of adaptability, such as generality, flexibility and elasticity [57]; versatility, convertibility and expandability [9]; flexible, available, changeable, movable, reusable, Refitable and scalable [58]; or flexible, active, dynamic, interactive, intelligent and smart [59]. These frameworks often assign slightly different meanings to the same terms.

Comparing the literature, these types of change and adaptability can be associated with the affected building layer(s) and frequency of change. Moreover, as summarised in Table 2, high-frequency changes—such as task-level (adjustability) and space-level (versatility) modifications—primarily affect the "stuff" and "space" layers, characterised by short lifespans and strong user control. These changes occur over short to medium timeframes and are mainly driven by users and owners.

**Table 2.** Types of building adaptability and stakeholder roles.

| Type of Change | Adaptability Type | Building Layer(s) Affected | Frequency of Change | Description | Roles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | O | U | M | $P_R$ | $P_M$ |
| Task | Adjustable | Stuff | High (day/month) | Changing the configuration of an individual setting to perform a different task (e.g., sit–stand desks in offices) | • | • | ○ | | |
| Space | Versatile (flexible) | Stuff, Space | High (day-10 y) | Changing the configuration of a space (e.g., moveable partitions) | • | • | • | • | ○ |
| Performance | Refitable | Services, Skin | Moderate (10–50 y) | Changing the performance of a building (e.g., access points for services) | • | ○ | • | • | ○ |
| Function | Convertible | Space, Services, Skin | Moderate (3–50 y) | Changing the use/function of a building (e.g., floor-to-soffit heights that allow office-to-residential conversion) | • | | • | • | ○ |

**Table 2.** *Cont.*

| Type of Change | Adaptability Type | Building Layer(s) Affected | Frequency of Change | Description | Roles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | O | U | M | $P_R$ | $P_M$ |
| Size | Scalable | Space, Services, Skin, Structure | Moderate/Low (20–50 y) | Changing the size of a building (e.g., over-sized foundations to accommodate extensions) | • | | • | • | ○ |
| Location | Movable | Structure, Site | Low (+50 y) | Changing the location of a building (e.g., modular pods that enable disassembly/deconstruction) | • | | • | • | |

Authors' elaboration, adapted from [59–63]. Stakeholders involved to make changes: O = Owner; U = User (building tenant, not owner); M = Manufacturer (construction enterprise); $P_R$ = Professionals (architect, engineer, etc.); $P_M$ = Policymaker. • = Leading role; ○ = Support role.

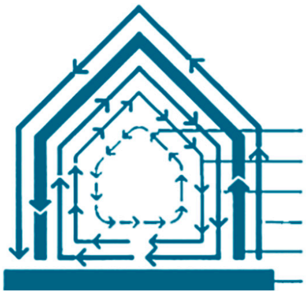
As adaptation complexity increases, interventions shift to longer cycles. Performance-related (refittability) and functional (convertibility) changes involve services and the envelope, typically over 10–50 years, requiring greater involvement from professionals and manufacturers alongside owners.

Size-related changes (scalability) extend to the structural layer, involving higher complexity, longer timeframes, and coordinated stakeholder input. Location-level changes (movability) are the least frequent and most resource-intensive, affecting the structure and site through disassembly and relocation, and are led primarily by owners, professionals, and manufacturers.

These adaptations are implemented through modifications to building layers (Table 3), a concept originating from Habraken's theory of supports. This theory distinguishes between the 'support'/base—including the structure, envelope and services—and the 'infill/fit-out—which includes partitions, fixtures and finishes [59,64,65]. The theory of supports directly influenced the *Open building* theory (also addressed to as "skeleton-infill", "Long-Life Housing", "Raw Space Housing" and "Free Plan Apartments"), which introduced the principle that building layers possess distinct life cycles and should be designed accordingly [60].

The building layer decomposition system theorized in the *Open building* concept was further developed by Brand in 1994, building upon Duffy's categorization. Brand's framework organized the building into six hierarchically arranged layers—site, structure, skin, services, space plan, and stuff—based on the lifespan and rate of change of each component or element. This stratification allows for the removal, replacement, addition, or upgrading of components without affecting other layers [59,63]. Additional revisions of Brand's categorization also add surroundings and souls (intended as the site beyond its perimeter and buildings users) [13]. These elements, not strictly related to the physical building, despite fundamentals, are considered beyond the scope of this research, which focuses on the building. Several other building layer categorizations also exist, such as those developed by BCIS and Level(s) [66,67]; however, these are less consistent within the literature on DfA.

**Table 3.** Building layers, elements and typical timescale of change.



| Layer | Building Elements | Change Timescale |
|---|---|---|
| Stuff | Furniture, equipment, possessions, etc. | Day/month |
| Space plan | Internal layout, partitions, finishes, etc. | 3–10 y |
| Services | Heating, ventilation, plumbing, etc. | 10–20 y |
| Skin | Cladding, roof, glazing, etc. | 20–50 y |
| Structure | Beams, columns, foundations, etc. | 50–300 y |
| Site | Physical location, legal boundary, etc. | Eternal |

Note: Brand's layers adapted from [68]. The change timescale was modified according to [69].

2.3.3. Design Strategies and Actions/Tactics

Designing for adaptability requires the adoption of specific design strategies, where a strategy is understood as a "Plan to achieve objectives" as defined in EN ISO 56000:2021. Strategies generally include a coordinated set of activities (actions/tactics in this paper) and the allocation of resources necessary to achieve objectives. Given the often-unclear definition of what an action is (BS EN ISO 9001:2015), in this document, design actions are spatial or technological building solutions and features implemented to make the building more adaptable.

The strategies presented in Table 4 form the basis for the development of a design-for-adaptability (DfA) plan, adopting design actions mapped from the academic literature that support diverse types of change and affect one or more building elements. The most frequently identified actions include: structural overcapacity, separation of building layers, increased internal ceiling height, reversible connections, freedom of plan reconfiguration (open plan), undefined/neutral or multifunctional rooms, building services overcapacity, and building technologies allowing for easy access to services. Several sources also cite the presence of central cores or double facades; however, these are excluded because they are considered to restrict internal flexibility and offer limited practical benefits. Variations in the level of detail used to describe actions are harmonised in Table A2.

As noted in the literature, several actions are classified according to performance levels—typically four—to represent increasing adaptability requirements.

**Table 4.** Design strategies by change type.

| Type of Change | Adaptability Type | Design Strategies |
|---|---|---|
| **Task** | **Adjustability** | **Design for building refurnishing**<br>Design actions for interior environments to facilitate rapid reconfiguration and changes of use through movable furniture, plug-and-play elements, etc., allowing individual settings to be efficiently adapted for diverse tasks. |
| **Space** | **Versatility** | **Design for building reconfiguration**<br>Design actions to change the configuration of the internal space by adopting non-load-bearing partition systems, an indefinite design (e.g., layout plan or finishes), and flexible internal walls and ducts to allow for repeated customization of floorplans during occupancy without structural intervention. |
| **Performance** | **Refittability** | **Design for building upgrade**<br>Structural and service design actions enabling system-level performance retrofitting, including accessible technical shafts, modular MEP systems, and component replaceability to facilitate future efficiency upgrades (e.g., HVAC, envelope, and energy systems) without major demolition. |

**Table 4.** *Cont.*

| Type of Change | Adaptability Type | Design Strategies |
|---|---|---|
| **Function** | **Convertibility** | **Design for building conversion**<br>Inclusion of design actions to accommodate diverse regulatory and functional requirements of a building by oversizing the structure and services, increasing floor-to-ceiling heights, adopting an indefinite design, etc. |
| **Size** | **Scalability** | **Design for building expansion**<br>Inclusion of design actions to change the size (scale) of a building, enabling physical enlargement or subdivision, by including external building extension (space and/or connection points for vertical elevation, horizontal additions, etc.), internal extension (conversion of basement, top storey, etc.), or subdivision and fusion of housing units (divisible service networks). |
| **Location** | **Movability** | **Design for building relocation**<br>Inclusion of design actions to change the location of a building by enabling disassembly, transport and reconstruction (e.g., reversible construction systems like bolted joints and dry assembly techniques, modular units, and transport-optimized structural design). |

Note: Adapted from Schmidt's adaptability framework. See Table A2 for specific design actions.

Accordingly, Table A2 characterizes each action in terms of performance level, the adaptability type it supports (after Schmidt) and the building layer involved (after Brand). In line with frameworks such as Level(s), the relative importance of actions is also acknowledged; for example, structural overcapacity enhances convertibility but does not contribute to adjustability or versatility. This analysis informed the development of the evaluation method described in Section 3.3.

## 3. Method

This research adopted a multi-stage methodological approach: (1) a literature review and analysis of existing adaptability assessment tools; (2) the definition of the theoretical framework and the subsequent development of the assessment tool, including preliminary case-study application to verify its correct operation; (3) a survey and a series of expert interviews to elicit specialist knowledge and support the validation of the methodology; (4) a review and refinement of the tool based on the obtained insights; and (5) final case-study-based testing. Further validation of applicability involving design practitioners is planned.

### *3.1. Tool Rationale*

The tool was developed based on the analysis of existing evaluation methods (Sections 2.1 and 2.2) and the theoretical framework defined in Section 2.3 to support the design and evaluation of adaptable buildings (or Adaptive Capacity) in new construction, refurbishment projects and existing buildings. Adaptability has a key role with respect to new construction, renovation and existing buildings [38].

The tool adopts Brand's building layer categorization, a recommended framework for design for adaptability [49]. An explicit correspondence between Brand's layers and those defined in the Level(s) framework is provided in the tool. In addition, the tool integrates the adaptability types proposed by Schmidt, as suggested in the literature [38].

The evaluation method, whose steps are described in detail in Section 3.3, employs a mixed-methods approach, combining qualitative assessments with numerical scoring. Each qualitative category is assigned a quantitative value.

Key innovations introduced with this tool include the explicit evaluation of the local context, the provision of disaggregated results by adaptability type and building layer, and the quantification of Adaptive Capacity through an index supported by design-oriented recommendations.

### *3.2. The Expert Survey and Interviews*

Experts who have developed building adaptability assessment methods and published research in the field were directly invited to participate (approximately 30 invitations). Participants completed an online survey covering their professional background and perspectives on building adaptability, including barriers, research gaps, measurement tools, and theoretical frameworks. Respondents who expressed interest were subsequently invited to interviews focused on the evaluation tool. Following a presentation of the tool, semi-structured questions elicited open feedback on its strengths and weaknesses, drivers and trends of change, the adoption of the risk-assessment approach (probability and severity), the definition of actions and performance levels, the weighting of actions, the final score and adaptability type, as well as the associated building layers and class.

This targeted expert elicitation aimed to synthesize informed judgments in a domain characterized by uncertainty, limited data or complex variable interactions [70], enabling experts to draw on their prior experience. Experts evaluated the overall methodology and the theoretical framework rather than the computational algorithm; this analysis was conducted through case studies.

### *3.3. Tool Algorithms*

The evaluation is conducted in the tool by modifying/filling white and light-orange cells and comprises four main steps implemented across dedicated worksheets (Figure 2):

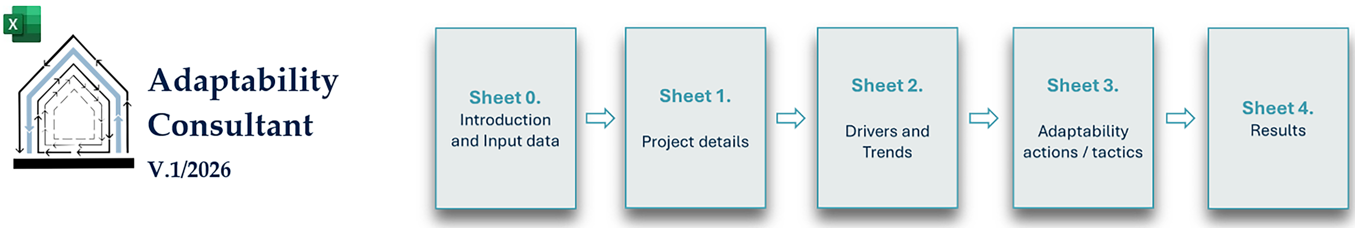



**Figure 2.** Tool's workflow.

- Step 1—Provide project details: This sheet collects information on the building/unit to be assessed and sets the scope of the evaluation, including the adaptability types or building layers to be considered. The project type (new construction, renovation or existing building) affects the performance threshold levels to be achieved, without affecting the input data required.
- Step 2—Define the project context (project details, drivers and trends): This tool assesses adaptability by first defining the contextual scope of the analysis (selecting the internal and external drivers and trends of change). This produces a site-specific evaluation to complement a non-contextualized assessment. The framework used to perform this evaluation is summarised in Table 5.

Consistent with the ABD method, the evaluation is grounded in the theoretical principle of identifying potential future uncertainties [47], used to prioritise adaptability actions/types in a specific context. This tool also quotes some common trends related to each driver, making it simpler to define the context (Table A1). Drivers (Figure 1) are mapped using the STEEP framework, and each driver is associated with one or more adaptability type and building layer. The drivers to be addressed must be fixed within a local context (e.g., municipality) and should not change, if the comparability of context-related analysis across buildings is to be ensured, to avoid introducing additional variability or bias. Other limitations of this approach are discussed in the Section 5.

**Table 5.** Framework for evaluating drivers of change.

| Group | Driver | Trend | Adaptability Type | Building Layer | Scope | Probability | | Severity | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Min | Max | Min | Max |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

Note: Drivers are grouped under the STEEP framework. Framework content represented by ellipses has been omitted for conciseness.

This step (driver's assessment), however, may be omitted, resulting in a non-site-specific assessment based on default values. Drivers do not alter the final adaptability score but influence the relative importance of each adaptability type ($Drivers\ Weight_{a,t,i}$), as described in Formula (1), modifying the thresholds required for each adaptability type. The weight/importance of each adaptability type is calculated as the product of the ratio between the total number of relevant drivers ($n.tot\ drivers_{a,t,i}$) proposed by the tool and the number of drivers actually addressed ($drivers\ addressed_{a,t,i}$) for each adaptability type, as well as the average probability ($Avg\ probability_{a,t,i}$) and average severity ($Avg\ severity_{a,t,i}$) values associated with the selected drivers of change. The ratio between the number of relevant drivers and the number of drivers actually addressed represents a penalization mechanism for limited coverage of drivers and normalizes differences in the number of drivers across adaptability types.

By integrating probability- and severity-based weights, the tool offers a more realistic representation of a building's likely need to accommodate change.

Average probability and average severity indices are derived from the mean values from the range assigned to each selected driver. Thresholds vary according to project type—new construction, refurbishment, or existing building.

$$Drivers\ Weight_{a,t,i} = \frac{n.tot\ drivers_{a,t,i}}{drivers\ addressed_{a,t,i}} \times Avg\ probability_{a,t,i} \times Avg\ severity_{a,t,i} \quad (1)$$

Each driver, as previously explained, is associated with a range of probability of occurrence and severity of impacts (from very low to very high), as defined in risk assessment theory [55], an approach also considered in the LBF method [40]. The assignment of probability and severity is based on a proxy-based approach, linking drivers to typical physical interventions (Table 6). Probability and severity are rated by selecting two values representing a range, using five levels from "very low" to "very high" (Table 7). *Probability* of drivers may be set based on the useful/service life of building layers involved in potential physical changes (the shorter the lifespan, the higher the probability), while *Severity* may be set according to estimated price/cost of common physical changes (the higher the refurbishment cost, the higher the severity) and evaluates the financial impact for building users. These parameters may be set by the user or fixed for a specific context, such as region. Probability and severity values contribute to the calculation of adaptability-type thresholds. Default values are currently provided.

**Table 6.** Reference values to define probability and severity.

| Work Type | Description | Frequency | Probability | Average Cost * | Severity |
|---|---|---|---|---|---|
| **Repair (maintenance)** | The reconstruction or renewal of any part of an existing building for the purpose of its maintenance or to correct damage. | 1–15 y | Very High | 1–4% | Very Low |
| **Alteration—Level 1** | Alterations include the removal and replacement or the covering of existing materials, elements, equipment, or fixtures using new materials, elements, equipment, or fixtures that serve the same purpose. | 7–30 y | Very High | 3–8% | Low |
| **Alteration—Level 2** | Alterations include the reconfiguration of space, the addition or elimination of any door or window, the reconfiguration or extension of any system, or the installation of any additional equipment (up to 50% of the building area). | 20–40 y | High | 8–15% | Medium |
| **Alteration—Level 3** | Alterations apply where the work area (of extensive space reconfiguration) exceeds 50% of the building area. | 20–40 y | Medium | 15–40% | High |
| **Additions (30%)** | Extension or increase in the floor area, number of stories, or height of a building or dwelling. | 50–60 y | Low | 10–50% | High |
| **Relocated buildings** | It includes the relocation of an entire building or parts of it. | +60 y | Very Low | 27–100% ** | Very High |

Note: Reference table to set probability and severity levels for drivers and trends. Probability (of trends related to drivers) is set according to frequency, which is set according to building element lifespan [67]. Severity is set according to 'average cost'. The work type categorization is adapted from [71]. * The average cost is assumed from [72–74] and refers to % of house value. Repair costs are assumed from [75,76]. ** Range of cost to rebuild a house [77].

**Table 7.** Quantitative values assumed for qualitative options.

| Range | Very Low | Low | Medium | High | Very High |
|---|---|---|---|---|---|
| Values | 0.2 | 0.4 | 0.6 | 0.8 | 1 |

Quantitative values are assumed for qualitative categories of driver probability and severity, as well as relative action weights.

- Step 3—Select adaptability design actions: The tool adopts a weighted sum approach to evaluate the building's adaptability, both in general and for specific adaptability types. Such a method is considered reasonable for evaluating adaptive potential and is adopted in different methods [78]. Among these, we can find Level(s), Flex 4.0., EN17680:2023, and the 'Adaptive Capacity of buildings' tool.

This approach (summarized in Table 8) entails selecting adopted design actions/actions to adopt—also referred to in the literature as physical attributes and design strategies [79]. Each action is linked to one or more adaptability types and building layers, as suggested in the literature [79] and seen in Flex 4.0, as certain actions span multiple adaptability types and building layers simultaneously.

**Table 8.** Framework for evaluating performance levels of design actions.

| n. | Design Action/Requirement | Performance Levels (PL) | | | | Adaptability Type | Build. Layer | Actual (PL) |
|---|---|---|---|---|---|---|---|---|
| ... | ... | 0 | 1 | 2 | 3 | ... | ... | 0–3 |

Note: Design actions and performance levels are provided in Table A2. PL = Performance Level. Framework content represented by ellipses has been omitted for conciseness.

Each action is associated with four performance levels (PLs), informed by literature and case studies, with any remaining values completed by the authors as needed (Table A2). Performance levels with quantitative values ensure objective responses rather than qualitative expert judgments, even though expert-based assessments are common methodologies [37].

The tool does not prescribe specific actions; rather, it identifies possible combinations, reflecting the principle according to which multiple pathways can lead to adaptability.

Actions are assigned a weight, as in Level(s) and the Adaptive Capacity Tool, which varies by adaptability type, acknowledging that actions are not equally relevant for different types of adaptability.

Certain actions are mandatory (for example, availability of additional buildable area on the parcel for scalable design). If mandatory actions are not addressed, the resulting score for that adaptability type is zero. Actions are independent and not mutually binding. The indices are calculated as Formula (2), which calculates the Adaptability Index ($Index_{a,t,i}$) for a specific adaptability type (e.g., Adjustable, Versatile, Refitable, Convertible, Scalable, or Movable) using a normalized weighted-sum method.

The numerator calculates the project's total achieved score by multiplying each relevant design action ($Actions_{a,t,i}$), related assigned performance level ($Performance\ Level_{a,t,i}$)—rated on a 0–3 scale as described in Table A2—and its assigned qualitative weight ($Action\ Weight_{a,t,i}$), a numerical value between 0.2 (Very Low) and 1.0 (Very High). The denominator represents the maximum theoretical score attainable for those same actions, calculated assuming every action achieves the highest possible performance level of 3.

The approach assumes that actions proposed in the tool are sufficient to achieve the required level for adaptable buildings.

Design actions are currently treated as independent within the algorithm: Formula (2) sums each action's weighted contribution linearly, without modelling synergies, redundancies or prerequisite relationships between actions. The only interaction currently captured is the binary gating rule for mandatory actions, which zeroes the relevant adaptability type score if unaddressed. This simplification is consistent with other weighted-sum tools reviewed in Section 2 (e.g., Flex 4.0, Level(s), etc.), but it means the tool may over-credit buildings that combine actions serving similar functions. A more advanced modelling approach—such as dependency-structure matrices [14], network analysis, or causal loop diagrams, as used in more complex adaptability assessment methods (Section 2)—could capture these interactions explicitly, at the cost of ease of use and lacking quantification of results.

- Step 4—Analyse results and iteratively refine the design: After selecting design actions and the related performance level, the final output is adaptability class scores. Two class scores are provided: a general adaptability score (independent of drivers) and a site-specific score. Both are calculated as a weighted average of the six main adaptability types using the corresponding driver weights [38]. Formula (3) aggregates the indices, calculated via Formula (2), adopting an unweighted arithmetic mean. Formula (4) determines a site-specific building adaptability class score ($Class\ Score_{site}$) by applying contextual weighting factors ($Drivers\ Weight_{a,t,i}$) to each individual adaptability index, as explained in Formula (1).

$$Index_{a,t,i} = \frac{\sum\left(Actions_{a,t,i} \times Performance\ Level_{a,t,i} \times Action\ Weight_{a,t,i}\right)}{\sum\left(Actions_{a,t,i} \times 3 \times Action\ Weight_{a,t,i}\right)} \tag{2}$$

$$Class\ Score_{general} = \frac{\sum Index_{a,t,i}}{6} \tag{3}$$

$$Class\ Score_{site} = \frac{\sum Index_{a,t,i} \times Drivers\ Weight_{a,t,i}}{6} \tag{4}$$

Results are accompanied by automatic comments to facilitate interpretation. Finally, an adaptability class is assigned using a letter code, which is compared against threshold values as indicated in Table 9. The class thresholds in Table 9—both the Class Index Threshold and the Driver-Specific Weight Threshold—are assumed as equal intervals (0.100 and 0.050, respectively) rather than being derived from the statistical distribution of scores or driver weights across a representative sample of buildings. The thresholds are calibrated through comparison with the three case studies described in Section 3.4. This approach was adopted for the current pilot version to ensure transparency and ease of interpretation in the absence of a sufficiently large and diverse reference dataset.

**Table 9.** Thresholds assumed for classes and indices.

| Class (New Buildings) | Class (Renovation/ Refurbishment; Existing Buildings) | Class Index Threshold | | Driver-Specific Weight Threshold (New Build.) | Driver-Specific Weight Threshold (Renov./Refurb.; Ex.) |
|---|---|---|---|---|---|
| A | A | > | 0.700 | 0.40 | 0.45 |
| B | B | > | 0.600 | 0.35 | 0.40 |
| C | C | > | 0.500 | 0.30 | 0.35 |
| D | D | > | 0.400 | 0.25 | 0.30 |
| E | E | > | 0.300 | 0.20 | 0.25 |
| F | F | > | 0.200 | 0.15 | 0.20 |
| G | G | > | 0.100 | 0.00 | 0.00 |

### *3.4. Case-Study-Based Testing*

To verify the consistency of the methodology and results, three well-known adaptable housing projects from different regions were analysed (Table 10). Data on building features were collected from academic and non-academic online sources, with conservative assumptions made where information was missing.

To ensure comparability, default settings for drivers and trends (Step 2, described in Section 3.3) were applied, automatically considering all drivers (Figure 1) with default probability and severity levels. The default actions weights (Step 3) were also applied. This approach ensures that the results reflect only the buildings' physical characteristics. Additionally, a context-specific evaluation was conducted to demonstrate the actual role of context weights. Since the goal of this activity is evaluating the methodology rather than accuracy of definition of the context, the scope (drivers) was set through AI tools (ChatGPT-5.6 Luna, in 1 September 2026) and revised using Google search (Table A1). The prompt was the following: *Considering the following list of drivers of change* (pasted), *could you define the scope of the core drivers affecting buildings within the context of [City of the case Study]? Please present the assessment in a table indicating "Yes" or "No" for each driver and motivate for your response comparing online sources*.

Default probability and severity levels are used to limit variability of results and ensure higher comparability between contextualised and non-contextualised analysis.

**Table 10.** Selected case studies.

| **Quinta Monroy/Elemental (QM); Iquique, Chile, 2004** | **Next 21 (N21); Osaka, Japan, 1993** | **Tila Housing Block (Tila); Helsinki, Finland, 2011** |
|---|---|---|
|  |   |  |
| Multiple buildings (n = 13), n. 93 units; 3 storeys; surface per unit: 36 $m^2$ to 70–72 $m^2$ (once expanded) | Single building, n = 18 units; 6 storeys; surface per unit: various values | Single building, n = 39 units; 6 storeys; surface per unit: various values, ranging from 50 $m^2$ to 100 $m^2$ (without mezzanine) |

## 4. Results

The following sections present the results of the survey, interviews, and case-study testing. The surveys and interviews serve to validate and reinforce the theoretical framework, while the case studies demonstrate the tool's functionality and applicability.

### 4.1. Survey and Interview Results

Of approximately 30 invited experts, 14 participated in the survey, and 8 participated in follow-up interviews. The sample reflects a high level of expertise: 10 respondents were university professors, and 13 had over five years of experience in building adaptability (Figure 3).

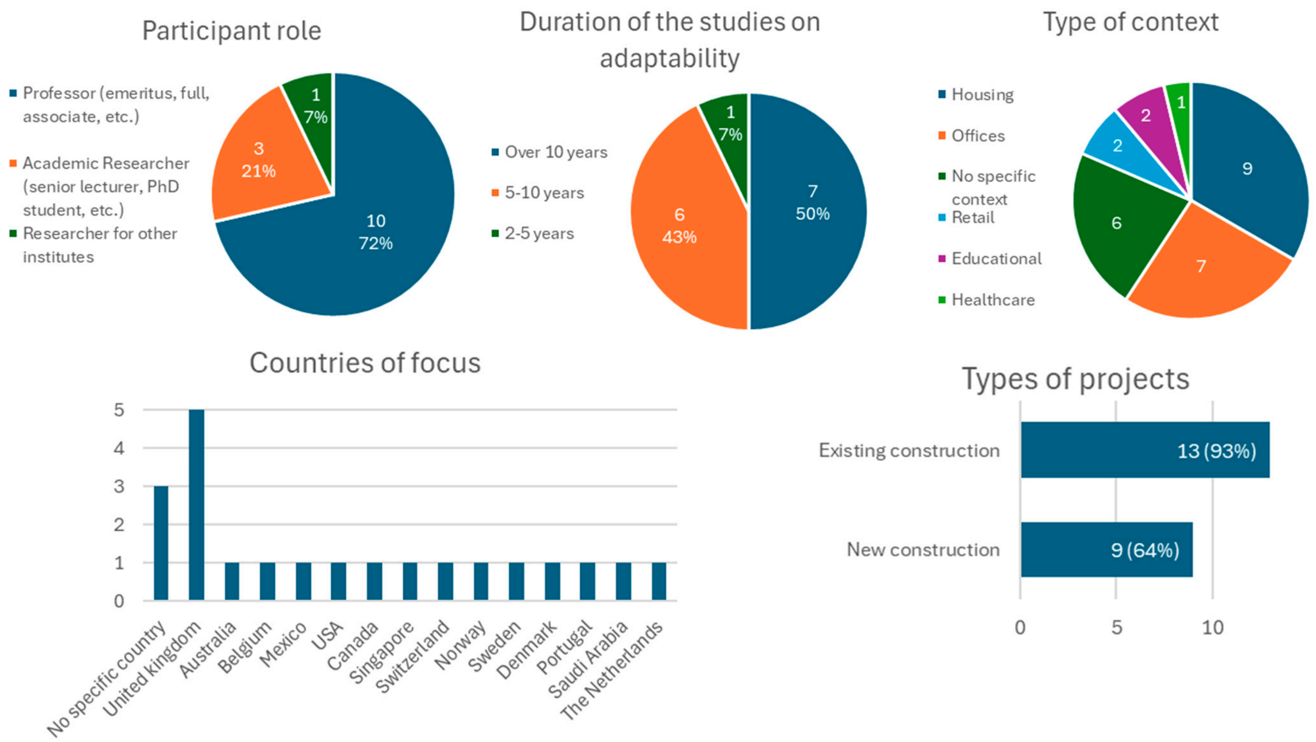



**Figure 3.** Information about participants.

The experts predominantly focused on housing (64%) and office buildings (50%), while 43% indicated no specific building context. Many respondents focused on the housing sector. Several participants also worked on retail, educational, and healthcare facilities.

Most respondents conducted their research in the United Kingdom or other European countries, resulting in broad coverage across Europe. A smaller number of studies were carried out outside Europe—specifically, in Mexico and Saudi Arabia. Their work primarily concerned existing buildings (93%, or 13 out of 14), although 64% (9 out of 14) also addressed new construction.

Seventy-one percent of respondents reported that building adaptability is rarely or only occasionally adopted by designers (Figure 4). Among the main barriers, 64% (9 out of 14) identified a lack of knowledge or skills among designers. One respondent additionally noted the absence of appropriate tools, although this option was not explicitly provided to avoid bias. Similarly, 64% emphasized the need for policy and design guidelines to overcome current barriers, while another respondent stressed the importance of defining and quantifying adaptability sub-characteristics under different conditions.

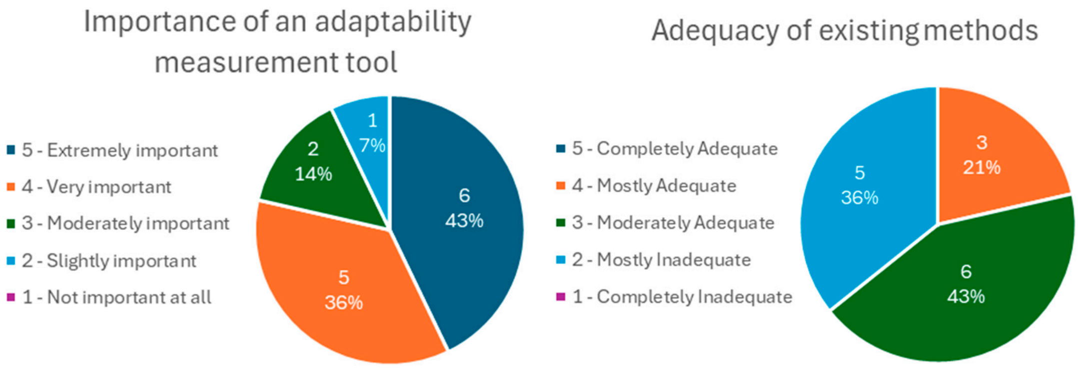



**Figure 4.** Perception of adaptability measurement tools.

These findings suggest the importance of capacity-building instruments, a conclusion reinforced by the fact that 79% of respondents considered tools for measuring adaptability to be extremely or very important in supporting decision-making by designers and technical professionals. However, only 21% (3 out of 14) regarded existing tools as mostly adequate, and none considered them fully adequate, as confirmed in the literature [80]. Respondents who criticised existing tools reported that: current tools primarily focus on sustainability rather than adaptability; adoption rates remain low; existing methods lack sufficient validation; there is limited understanding of adaptability sub-characteristics and how they should be assessed across different contexts and tools; data availability is limited, scopes of application are narrow, and tools are often fragmented or not user-friendly; tools do not adequately account for the diversity of building typologies; and real costs are generally not considered.

Finally, to validate the theoretical frameworks incorporated into the tool, respondents were asked to indicate their level of agreement with their use (Figure 5). A total of 93% (13 out of 14) agreed with the application of Brand's building layers, while 78% agreed with the adoption of Schmidt's framework of adaptability types. The only noted disagreement concerned the view that these frameworks are not fully exhaustive and contain overlapping concepts. However, no consistent framework was proposed, as respondents acknowledged that such limitations reflect broader gaps in the literature [47].

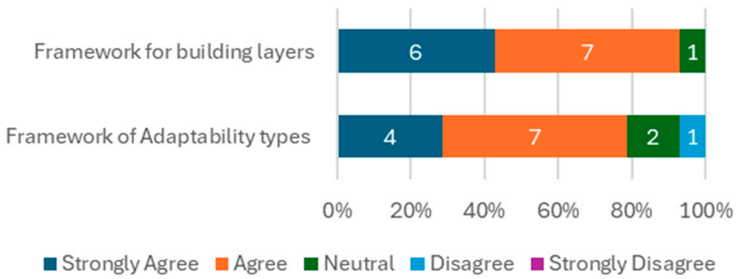



**Figure 5.** Agreement with theoretical frameworks adopted in the tool.

The online interviews involved eight respondents who expressed interest in reviewing the evaluation methodology. After a presentation of the tool, semi-structured questions elicited feedback on its strengths and weaknesses, drivers of change and emerging trends, the adoption of the risk-assessment approach (probability and severity), actions and performance levels, the weighting of actions, the final score and adaptability type, and the associated building layer and class.

Overall, respondents appreciated the structure and clarity of the tool while identifying limitations and opportunities for enhancement discussed below.

According to the experts, the tool is comprehensive and grounded in existing theoretical discussions and frameworks (Experts 2, 4, 6, and 7), adopting 'fair' simplifications to manage, diverse dimensions, complex interactions and uncertainty in the field (expert 7). However, this comprehensiveness may also become a limitation if the evaluation process becomes time-consuming (Expert 6), requiring, for example, the pre-setting of default values.

Expert 3 also noted that sheets should remain concise, with additional information to be displayed when requested by the user.

Experts 7 and 8 highlighted that the structured layout is easy to understand and that using Excel facilitates adoption and interoperability with other tools. However, experts recommended enhancing the tool with embedded guidelines and recommended filtering information to reduce complexity (Experts 3 and 4). Finally, Expert 3 suggests that it could be converted into an open Web-based tool.

Step 1 of the analysis, the part on project details, initially lacked specificity (Expert 3), and adding more details should affect following sheets, such as the applicability of actions. Coherently, other experts noted that the type of building, its use, and the tool's user role could affect drivers and actions (Experts 4 and 5). These comments suggest the extension of this part rather than just serving as an informative section.

Experts generally appreciated the inclusion of driver and trend analysis (Step 2), a strength in comparison to other tools (Expert 1), as it supports the needed contextualisation of adaptability design (Experts 1, 2, 3, 7, and 8). They believe this step helps to focus on goals and makes the concept tangible and easier to prioritize actions; however, currently, it can be a difficult subjective exercise (Experts 3, 5, and 7). Some experts suggested that users should be able to adjust the drivers and that the step might be optional if the user lacks sufficient knowledge (Experts 3 and 4). Designers may not always be able to evaluate these aspects, and the values may vary across regions, building types, and other contextual variables (Experts 6 and 8). Eventually, default values or clearer guidance should be provided on how to adapt them to regional/local conditions (Experts 4, 5, 7, and 8). Some variables for this contextualization (impacting the probability and severity of a driver) should be better defined in the future, perhaps in the field of statistics (Expert 7). The evaluation of severity could be analysed more in detail in terms of economic cost, as the cost could change a lot in relation to context (Expert 1).

Experts 1 and 7 suggested a simplified version with only essential drivers, with a consistent process to define them. Expert 8 noted that unexpected events may also be relevant and that the list could, in principle, be expanded.

In conclusion, a series of values derived from quantitative references (Table 5) were qualitatively pre-set. These allow users to refine drivers; alternatively, users may rely on default values or omit this step. Further research is required to develop objective criteria for adjusting these values.

The evaluation of adaptability design actions and performance levels (Step 3) is considered a reasonable and methodologically sound approach (Experts 2, 7, and 8), provided it is linked to building use (Expert 6). The four performance levels were viewed as helpful in simplifying interpretation while maintaining conceptual clarity, improving usability for practitioners (Expert 7) and supporting the translation of adaptability strategies into technical criteria (Experts 5 and 6). However, their usefulness depends on the appropriateness of performance requirements (Expert 8) and clear definitions of what they apply to (e.g., specific building surfaces), as noted by Expert 1.

Expert 5 questioned whether all relevant actions are included and whether the system risks becoming too rigid, suggesting periodic revision as research advances. Expert 8 added that actions should be tailored to building type, project phase, and user roles, enabling users to filter what falls within their control; the selection of relevant building layers partially supports this goal.

Experts 4 and 3 similarly observed that the relevance and level of detail depend on the audience and project phase, with some actions being too detailed for early-stage design. In response, the tool has been positioned primarily for final design stages while still offering important early-stage guidance.

In the tool, each action is weighted to reflect its relative importance for different adaptability types. All experts agreed that weighting is essential. The absence of weights implicitly treats all actions as equally important (Expert 8). These weights are currently assigned qualitatively by the authors. Expert 7 considered the current subjective weighting scheme acceptable and pragmatic for a pilot version of the tool and suggested that future iterations should strengthen methodological rigor by testing the consistency and reliability of the weighting system, as well as in relation to different contexts, professional roles or aspects such as building type and owner. (Expert 2, 5, 6, and 8). Analytical methods such as Cronbach's alpha, the Analytic Hierarchy Process (AHP), or sensitivity analysis were identified as suitable techniques for validating the weights (Expert 1, 7).

At this stage, it is suggested that it may be beneficial for users to adjust the weighting (adopting standardised scenarios or baseline weightings), as the perceived importance of each action can vary depending on project priorities and context (Expert 4).

Regarding the analysis of results (Step 4), experts supported the use of indices and classes to present outcomes. This was viewed as a sound methodological choice, consistent with established multi-criteria evaluation approaches (Expert 7). Results presented as indices or classes were considered easy to interpret and communicate, particularly for practitioners and policymakers (Expert 3). Experts emphasised the need to clearly explain what each score means for different audiences (Experts 4, 6).

While the use of indices is appropriate, it remains a simplification of the complex dynamics underlying adaptability (Expert 7). Experts noted that the normalization method must be clear and transparent, as clarity facilitates comparison across projects and can motivate designers to pursue higher adaptability ratings (Expert 7). Expert 8 suggested refining the general index by distinguishing site-specific drivers and providing weighted average scores rather than relying on averaged values.

Experts also stressed the value of providing detailed sub-scores by adaptability type and building layer (Experts 3 and 5) because trade-offs may exist between adaptability types and detailed outputs can better support decision-making (Expert 8). However, detailed information may be difficult to process, and Expert 1 suggested offering more granular results "on demand" to improve usability.

Assigning adaptability scores by building layer was viewed as logical and practical (Expert 7), as adaptability can manifest differently across layers. Nonetheless, this remains a model simplification, given the complex interdependencies between layers.

Several experts also recommended validating the scoring and interpretation of results through empirical data, expert feedback through Delphi studies, or case-based calibration (Expert 7 and 5). Future versions could also incorporate more advanced analytical methods—such as network modelling or dependency-structure analysis—to account for interactions and dependencies across building layers (Expert 7).

### *4.2. Case-Study Results*

To test the consistency of the tool, three case studies are analysed. To ensure comparability across case studies, default settings for drivers and trends (Step 2, Section 3.3) were applied to all case studies, automatically considering all drivers (Figure 1) with default probability and severity levels. The default actions weights (Step 3) were also applied.

As explained by Formula (1), when all drivers are considered, due to their number and associated average probability and severity, the results indicate that adjustable design is most strongly required, whereas movable or convertible design is comparatively less necessary in this context (Table 11).

**Table 11.** Weighting of adaptability type in relation to selected drivers and related thresholds.

| Adaptability Type | n. Drivers (Addressed) | Drivers Index | Average Probability | Average Severity | Weight | Thresholds (Independent from Drivers) | Thresholds (Driver-Specific Context) |
|---|---|---|---|---|---|---|---|
| Adjustable | 23/23 | 1.00 | 0.60 | 0.54 | **0.33** | **0.50** | **0.50** |
| Versatile | 22/22 | 1.00 | 0.52 | 0.52 | **0.27** | **0.50** | **0.40** |
| Refitable | 29/29 | 1.00 | 0.53 | 0.55 | **0.29** | **0.50** | **0.40** |
| Convertible | 10/10 | 1.00 | 0.43 | 0.56 | **0.24** | **0.50** | **0.30** |
| Scalable | 9/9 | 1.00 | 0.49 | 0.58 | **0.28** | **0.50** | **0.40** |
| Movable | 2/2 | 1.00 | 0.50 | 0.50 | **0.25** | **0.50** | **0.30** |
| | | | | | Average | **0.50** | **0.38** |

Weights are calculated from Formula (1). Thresholds are assumed from empirical tests.

Normalised weights range from 0.24 for convertible to 0.33 for adjustable design, a spread that reflects the narrow differences in a driver's probability and severity, once combined. This explains the range of thresholds (driver-specific context), spanning between 0.3 and 0.5.

Driver-specific thresholds are calculated based on the assigned weights (Formula (1)). Thresholds that are independent of drivers are also adopted from Table 11.

The weighted scores of the design actions for each adaptability type, as shown in Table 12, indicate that most actions contribute primarily to versatile and convertible design (with 64.2 and 63.6 points), whereas fewer actions support adjustable or movable design (24.6 points).

Regarding the adopted actions, as more clear in the final score for each adaptability type, calculated according to Formula (2), Next 21, compared to Quinta Monroy and Tila, performs better in adjustability, versatility, convertibility, and movability, largely due to the clear division of building layers and its capacity for disassembly. By contrast, the Tila Housing Block appears to be more Refitable and scalable because its units are designed to be divided or merged. A low score is generally given in the tool for the 'movable' adaptability type when projects adopt wet connections and limited attention to disassembly (a mandatory requirement for movability) Quinta Monroy achieved a low adjustability score, resulting from constrained internal space that restricts variations in furniture layout unless adjustable furniture is provided. Moreover, despite achieving the threshold set, the potential for expansion is partially limited by wet connections, unit size, constraints on enlargement, and the practical impossibility of division.

**Table 12.** Scores from adopted design actions.

| Adaptability Type | Total Score of Actions (Available) | Score of Actions (Adopted) | | | Adaptability Index (from 0 to 1) | | |
|---|---|---|---|---|---|---|---|
| | | QM | N21 | Tila | QM | N21 | Tila |
| Adjustable | 15.0 | 2.8 | 10.0 | 7.4 | 0.19 | 0.67 | 0.49 |
| Versatile | 63.6 | 25.4 | 36.0 | 34.8 | 0.40 | 0.57 | 0.55 |
| Refitable | 42.0 | 14.2 | 19.2 | 20.4 | 0.34 | 0.46 | 0.49 |
| Convertible | 64.2 | 24.4 | 32.0 | 31.4 | 0.38 | 0.50 | 0.49 |
| Scalable | 39.0 | 16.2 | 17.2 | 23.0 | 0.42 | 0.44 | 0.59 |
| Movable | 24.6 | 0.0 | 13.8 | 10.4 | 0.00 | 0.56 | 0.42 |

Results obtained from Formula (2) selecting actions' performance levels (Table A2).

More broadly, adjustability and movability show the widest spread among the three buildings (0.19–0.67 and 0.00–0.56), while versatility and convertibility remain more consistent (0.40–0.57 and 0.38–0.50, respectively), suggesting that certain adaptability types may be significantly constrained if they are not anticipated during design phases.

Finally, the occasional lack of available information—and the resulting choice to adopt conservative assumptions—may have influenced the final results.

As shown in Table 13, Quinta Monroy met the thresholds for convertible and scalable design within the driver-specific context. Next 21 satisfied the thresholds for adjustable, versatile, and movable design in the driver-independent scenario, and it achieved all thresholds in the driver-specific context. The Tila Housing Block met the thresholds for versatile and scalable design in the driver-independent scenario and achieved all thresholds in the driver-specific context, except for 'adjustable'.

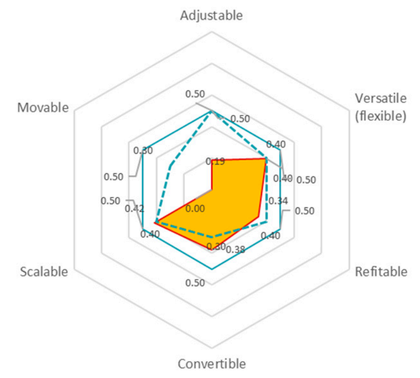
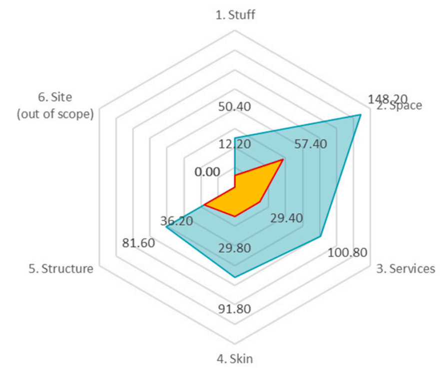
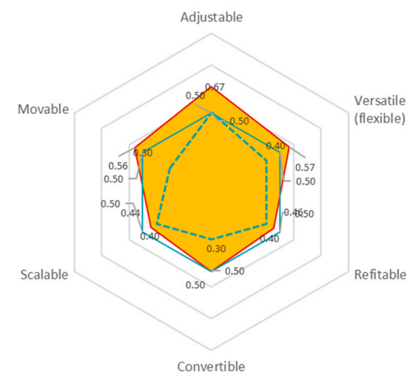
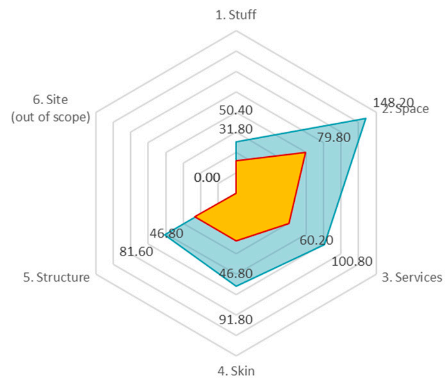
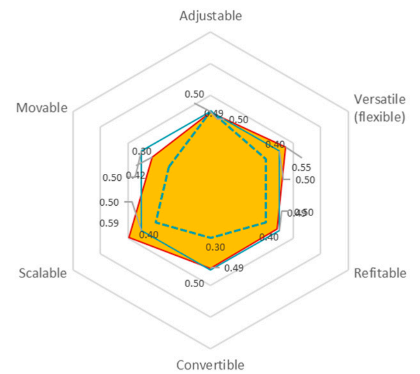
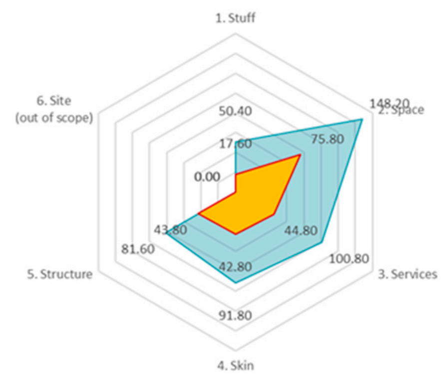
With respect to the overall indices (class scores), the driver-independent and driver-specific contexts yield almost identical results, as the variation in weights is small (ranging from 0.24 to 0.33). The table further indicates that, consistent with the detailed results by building layer, in all cases, there remains significant room for improvement. Specifically, actions related to internal space (internal layout, partitions, finishes, etc.) and services (heating, ventilation, plumbing, etc.) can be implemented to achieve higher adaptability.

As anticipated in Section 3.4, a context-specific evaluation was conducted, to demonstrate the actual role of context weights. The analysis suggests that the three cities share most core drivers of building change, particularly demographic and lifestyle changes, changing household needs, technological development, energy efficiency, housing-market dynamics, maintenance, climate pressures, and regulatory frameworks.

However, the intensity and origin of these pressures differ across contexts. Osaka and Helsinki show greater similarity in their driver profiles, whereas Iquique seems to be distinguished by lower emphasis on health and sustainability concerns, greater influence of supply-chain and resource-availability pressures, lower levels of innovation in design and construction, and weaker economic incentives for building adaptation.

The localized analysis further demonstrates that these contextual differences directly affect the thresholds required to satisfy each adaptability type. Compared with the independent threshold set at 0.50, the localized thresholds are generally lower, but the magnitude of the reduction varies considerably between contexts and adaptability types (Figure 6). For example, the threshold for the Movable type decreases from 0.50 to 0.10 in all analysed contexts, representing the value that changes the most, while the Adjustable threshold decreases to 0.40, representing the value that changes the least. Similarly, the overall Adaptability Index threshold decreases from 0.50 under the independent assessment to 0.25 for QM and 0.28 for both N21 and Tila.

**Table 13.** Comparison of final scores.

| Building | | Detailed Results by Adaptability Type | Detailed Results by Building Layer |
|---|---|---|---|
| **Quinta Monroy/Elemental;** Iquique, Chile, 2004 | |  |  |
| **CS1** | **CS2** | | |
| 0.287 | 0.287 | | |
| **Next 21;** Osaka, Japan, 1993 | |  |  |
| **CS1** | **CS2** | | |
| 0.532 | 0.535 | | |
| **Tila Housing Block;** Helsinki, Finland, 2011 | |  |  |
| **CS1** | **CS2** | | |
| 0.505 | 0.506 | | |

Results obtained from Formulas (3) and (4); CS1 = class score independent of drivers; CS2 = class score for the driver-specific context. Legend for adaptability types: Adaptability index, Threshold Independent from drivers, Required by context; legend for building layers: Maximum score, Score achieved. Note: The scores by building layer are not normalized in order to distinguish them from the adaptability type score, which constitutes the main index.

Importantly, the Adaptability Index values of the case-study buildings, themselves, remain unchanged under localization (Table 12); what changes is the threshold against which their performance is evaluated. This distinction is fundamental to the proposed approach: the capacity of a building to adapt is an intrinsic characteristic of the building and therefore does not change with context, whereas the level of adaptation required or expected may vary according to the drivers of change prevailing in a specific context.

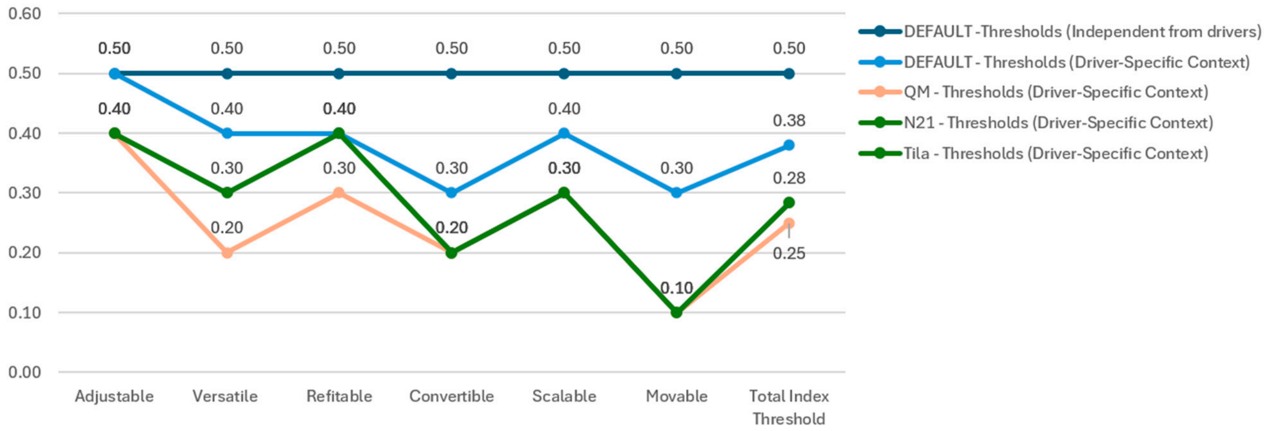



**Figure 6.** Threshold variation across scenarios (analysis of drivers).

## 5. Discussion

### *5.1. Discussion About Surveys, Interviews and Case Studies*

Expert elicitation (as described in Section 4.1) played a central role in refining the tool, and the number of expert participants—14 for the survey and 8 for the interviews—was considered sufficient for this purpose. Thee disciplinary backgrounds of participants were reasonably diverse; however, representation of experts with experience in developing and emerging countries was limited. This gap suggests the potential need for further research, to prevent risks of low applicability to such contexts. This risk was mitigated by the inclusion of a case study located in Chile, which is classified as a developing country.

Overall, experts expressed a high level of acceptance of the tool, confirming that academics value an approach that adopts the weighted-sum approach [78]. Nonetheless, although participants were explicitly encouraged to provide candid and critical feedback, a blind review process would be necessary to validate the level of acceptance reported. The elicitation process also highlighted several areas for future improvement, including the need for validation by practicing designers, who, beyond academics, constitute one of the primary intended user groups of the tool.

Finally, as noted by Expert 7, it is important to acknowledge that certain simplifications are inherent methodological limitations, reflecting the fact that adaptability assessment remains an emerging and relatively underdeveloped research domain, discussed as fragmented in the scientific literature [80].

The analysis of the three case studies provides valuable insight into the applicability of the tool and how adaptability can contribute to long-term housing sustainability and affordability, such as to deliver housing at lower initial costs while enabling future changes [81]. Across the three cases, the tool proved effective in distinguishing between different types of adaptability and in identifying where specific design actions contribute—or fail to contribute—to adaptive performance.

Although these buildings are widely recognised for their adaptive capacity, the assessment revealed substantial variation across building layers and adaptability types; buildings do not necessarily score uniformly once adaptability is disaggregated into distinct types and building layers. This finding reinforces a core proposition of the research: adaptability is not a homogeneous attribute but a multidimensional property that requires holistic evaluation [39]. However, in certain instances, the results were influenced by limited or inconsistent documentation, leading to the adoption of conservative performance levels. This suggests that future research would benefit from more systematic data collection and closer collaboration with design teams and building users.

The scientific literature and the case studies were used to define the set of design actions and their performance levels (Table A2), thereby establishing requirements based on recognised best practices. For this reason, Next 21 and Tila Housing Block, widely considered adaptable buildings, received only a Class C score, as they are not exemplary across all adaptability dimensions. This also explains why Quinta Monroy, despite its international recognition as a successful incremental housing strategy, demonstrated low adaptability in several areas. Despite good performance in scalability potential, its dependence on wet connections, limited internal space, and minimal disassembly potential significantly constrained its overall adaptive capacity in relation to the proposed evaluation method.

This divergence also illustrates the diagnostic value of the developed tool.

Differences between the driver-specific and general adaptability scores indicate that meeting local contextual requirements does not necessarily result in a fully adaptable building. In this study, the divergence between the two class score indices is limited, as all contextual drivers were first uniformly applied to ensure comparability across the three case studies. The localized context analysis (Section 4.2, Figure 6) demonstrates that buildings may achieve different adaptability evaluations depending on the local contexts, without necessary physical modification. This provides evidence that Step 2 meaningfully differentiates evaluation outcomes according to contextual requirements. At the same time, the finding that movability's threshold dropped most sharply (0.50 to 0.10) across all three cities while adjustability's threshold barely moved (to 0.40) indicates that the number of drivers proposed in the tool, as well as their relationship with adaptability types, influences outputs. It is also worth noting that the driver scope for the localized analysis was established using generative AI and cross-checked against Web sources (Section 4.2, Table A1). This was appropriate for testing of the tool's sensitivity to contextual differences but should not be considered a validated method for practical application. Future applications should instead incorporate local expert knowledge and statistics, with future research also comparing AI-assisted, expert-based, and data-driven approaches to contextual scoping.

Moreover, the current version of the tool places greater emphasis on adjustability, versatility, and refittability, reflecting their frequent relevance, while movability, convertibility, and scalability are less commonly required, a distinction that is incorporated into the tool's structure.

Finally, the limited sample size represents a current constraint of the study, a challenge also noted in the literature, where many adaptability assessment methods are validated through intra-model comparisons and a small number of case studies [40]. Future work should involve testing the tool on a larger and more diverse set of buildings, comparing it with alternative methods, and conducting statistical analyses to identify generalizable key actions and performance levels. This analysis should also be conducted on buildings and contexts selected to maximise variation in driver profiles.

### *5.2. Discussion About the Tool Methodology*

The development of the adaptability assessment tool addressed persistent limitations in existing evaluation methods by providing a structured, transparent, and replicable means of assessing adaptive capacity. Unlike many existing tools, which are often qualitative, highly subjective, or conceptual [45,47], the proposed method offers a practical, Excel-based tool applied with relative ease, enabling preliminary analyses to be completed within a few hours. Its focus on technological parameters and quantifiable requirements responds to a gap in the current literature.

Step 1 of the tool, which allows users to customise the analysis by entering project-specific information, in its current version, does not affect proposed actions or performance levels, although future iterations may expand its influence. At this stage, the required inputs—project name, ownership, location, year, building height, building size, number of users, building type (currently limited to residential), and project type (new construction, renovation, or existing building)—were intentionally kept minimal.

Additional project characteristics, such as those included in Level(s) [82] (like climate zone and building form or structural system, envelope type, etc.), could be incorporated to filter and interpret results.

The tool currently incorporates a systematic analysis of contextual drivers (Step 2), thereby grounding adaptability requirements in the specific local conditions in which buildings operate. This analysis is a central academic contribution of the framework and recognises that adaptability is not a static attribute but is shaped by internal and external pressures that influence design priorities. For residential buildings, the drivers identified in the tool (Figure 1) generally direct priority on adjustable, versatile, and Refitable design. In contrast, movable and convertible strategies appear less relevant.

Nonetheless, drivers may vary by country, region, building typology, use type, and user group; the tool therefore allows users to adjust drivers and their associated probability and severity values accordingly.

For this reason, further research is required to improve technical rigour and objectivity, reducing the risk of additional variability or bias in the selection of local drivers of change. One possible approach could be to define drivers based on statistical analysis and regional policy strategies.

The tool explicitly links design actions to adaptability types and building layers, generating indices for each adaptability type, which could enable the creation of a project portfolio for benchmarking and statistical analysis. The analysis shows that because many design actions are attributed to multiple adaptability types, the six sub-indices are influenced by shared actions rather than independently in each dimension. Users, beyond considering the class score, should primarily focus on sub-index profiles and consult the action-to-type mapping (Table A2) when comparing sub-index profiles across buildings.

The design actions included in the tool (Table A2), as evaluated in Step 3, represent the most commonly cited strategies for enhancing adaptability in residential buildings—although many also apply to other building functions and could be refined accordingly. In practice, action requirements may be specific to building functions and countries and should be revisited in light of local building codes, climatic conditions, and construction practices. Additional actions may be needed for certain adaptability types. Priority within actions should be given to those targeting building layers and elements with short service lives, as they are more likely to require attention.

The final results, as presented in Step 4, include threshold values for achieving different types of change depending on the intervention type (new construction, renovation, or existing buildings), the preferred adaptability type, and the building layer under consideration. These results confirm the view expressed in the literature that adaptability assessment should be treated as a multi-criteria decision analysis informed by technical specification data [38]. Nevertheless, gaps remain with regard to empirical socio-economic and environmental data; although drivers and trends partially address these, further integration of data, for instance, cost–benefit analysis, could improve the robustness and relevance of results [39]. Moreover, the tool adopts a weighted-sum approach (while accounting for different levels of importance among actions); however, alternative aggregation methods, such as the Square Root of the Sum of Squares (SRSS), could also be explored.

Finally, the findings indicate that buildings designed with separation of layers—consistent with *Open Building* theory [83]—and with provisions for disassembly, as well as robustness in size, structure, and systems, are more likely to achieve high adaptability scores under this evaluation method.

## 6. Conclusions

As previously discussed, the tool developed and tested in this research evaluates the adaptive capacity of buildings and can support academics, designers, and technical professionals by providing structured decision-making assistance for existing buildings, as well as early and detailed design stages. It can help stakeholders to assess how their design decisions influence a building's ability to accommodate change over its lifecycle. In addition, the tool may support policymakers and project owners in formulating project requirements, contributing to future-proofing of the building sector.

The adoption of the tool during design has the potential to influence design directions [38] and facilitate the adoption of lifecycle approaches [47]. It is best suited to preliminary and technical design and can help generate modified design scenarios that can subsequently be evaluated through complementary methods such as LCA or LCC. When applied at later stages or in existing contexts, it can serve as an evaluative benchmark. However, the technical requirements leading to performance levels are typically not yet defined at the conceptual stage, and their absence was shown in this study to lead to conservative default assumptions that can understate a building's true adaptive potential (Sections 4.2 and 5.1).

Nevertheless, at early design stages, the tool can serve as a framework to support decision-making by identifying adaptability requirements before detailed technical specifications are established.

The methodological choices underpinning the tool demonstrate that a structured, weighted-sum approach can enhance transparency, consistency, and usability in the evaluation of adaptability. Although the methodology was developed specifically for residential buildings, it can be adapted for other building typologies, provided that certain aspects are recalibrated: (i) contextual drivers (Step 2), since relevance, probability, and severity of contextual pressures differ by local context; (ii) design actions and their weights (Table A2, Step 3), since layer-specific interventions and quantitative requirements relevant to residential adaptability may not transfer directly to other typologies with the same importance; and (iii) threshold values (Table 9), since acceptable performance levels and service-life expectations vary by typology.

The tool was applied to three case studies, considering both the external context and the characteristics of the buildings themselves. Under default settings, all three case studies were assessed against a uniform 0.50 threshold for each adaptability type. Once Step 2 was run using default settings, the resulting priority weights were 0.33 for Adjustable, 0.27 for Versatile, and 0.29 for Refitable. When the analysis was instead based on drivers scoped to each building's actual city, the localized context analysis (Section 4.2, Figure 6) suggested adaptability types to be prioritized, and thresholds diverged substantially. The largest change concerned Movability, whose threshold decreased from 0.50 to 0.10, whereas the Adjustable threshold decreased to 0.40, representing the value that changed the least, maintaining high priority, while the overall Adaptability Index threshold decreased from 0.50 to 0.25 for QM and 0.28 for both N21 and Tila.

While threshold values change under the localized analysis, the buildings' Adaptability Index values remain unchanged. This reflects a core proposition of the localization approach: a building's intrinsic adaptive capacity does not change with context; rather, the level of adaptation required is determined by the specific conditions of the context in which the building is located.

The tool distinguishes performance levels across different adaptability types that could otherwise be concealed by a single aggregate evaluation. Among the three buildings, Adjustability and Movability show the widest variation (0.19–0.67 and 0.00–0.56, respectively), whereas Versatility and Convertibility remain more consistent (0.40–0.57 and 0.38–0.50). This suggests that certain adaptability types may be substantially constrained when they are not explicitly anticipated during the design stage. N21 achieved the highest overall performance, while Tila performed better in terms of Scalability and Refittability.

While the current version provides a robust foundation, several limitations of the current study offer opportunities for further research, and refinement will be possible as evidence is collected.

Although academic expert elicitation was used to improve the tool, its validation with practicing designers and construction specialists remains unaddressed.

The mapping relationship between Schmidt's six adaptive types, Brand's building layers, and drivers of change and adaptability actions is primarily derived from the existing scientific literature and has not been empirically verified in the context of real architectural practice. While both frameworks are widely recognised as valuable and have been adopted in previous studies for evaluation of adaptability [48,49], the proposed mapping serves to develop a first version of an evaluation tool rather than an empirically validated (market-ready) tool. As discussed in Section 4.1, there is broader scientific support for the use of such frameworks in evaluating building adaptability. However, their limited adoption and application in real architectural practice also highlight the need for further empirical investigation, particularly through architectural case studies and practitioner-based research as an important direction for future work.

Another limitation concerns the definition of levels for probability and severity criteria for contextual drivers. These values were established by the author based on service-life data and typical work costs; however, a more rigorous, statistical, and quantitative analysis could strengthen this part, eventually adding missing drivers. Future work may incorporate analysis of primary drivers through the use of historical datasets, Bayesian statistics, expert elicitation, or frequency analysis of how often specific drivers occur, as well as their co-occurrences. Such an approach would allow probability ranges and severity thresholds to be grounded in empirical evidence.

Although actions were derived from academic literature and existing case studies, further research is also needed to validate, customize, and expand the list of design actions used in the tool. A further limitation concerns the aggregation of actions across adaptability types. Design actions are currently treated as independent within the algorithm: Formula (2) sums each action's weighted contribution linearly, without modelling synergies, redundancies or prerequisite relationships between actions. This simplification is consistent with other weighted-sum tools reviewed in Section 2 (e.g., Flex 4.0, Level(s), etc.). Because each type-specific index (Formula (2)) is normalized independently, actions attributed to multiple types do not distort any single sub-index. However, when indices are aggregated into the overall Class Score (Formulas (3) and (4)), such an action is counted once per type to which it is attributed, potentially inflating scores for buildings whose selected actions are concentrated in multi-attributed items. The only interaction currently captured is the binary gating rule for mandatory actions, which zeroes the relevant adaptability type score if unaddressed. This issue is compounded by conceptual overlap among Schmidt's adaptive types, as also noted by survey respondents (Section 4.1).

Future refinements could exclude or capture these interactions, exploring non overlapping actions or frameworks (currently not identified), fractional attribution (splitting an action's weight across its associated types), covariance-aware aggregation to mitigate double counting or dependency-structure matrices [14], network analysis or causal loop diagrams. For the current pilot version, users should read the sub-indices as independent to improve each adaptability type, despite the existing correlation, and interpret aggregated indices as indicative.

In addition, the relatively small number of case studies examined to date limits the robustness of the threshold ranges for class scores, the evenly-spaced A–G letter-grade bands or the per-type driver-specific thresholds (Tables 9 and 11), and weighting schemes. Broadening the analysis to include a larger and more diverse set of buildings across typologies and geographical contexts would enable more accurate calibration and the identification of actions and performance levels [78]. From this broader evidence base, cut points could be derived using methods such as percentile-based binning, cluster analysis (e.g., natural breaks/Jenks), or Delphi-based expert consensus, ideally validated against independent outcome data. Such an expanded dataset could also support investigations into trade-offs, particularly the balance between adaptability, affordability, and sustainability. For example, while certain adaptability features may enhance long-term flexibility, they may also introduce drawbacks.

Another limitation relates to the assignment of a relative importance value for each action in relation to adaptability type, currently based on informed judgement. A larger empirical evidence base would strengthen these assignments. Comparative analyses with existing adaptability assessment methods would also be beneficial to understand complementarities and divergences. Looking ahead, the methodology may serve as the foundation for a Web-based tool capable of offering interactive guidance, providing context-sensitive information on demand, managing output data more effectively, suggesting design strategies and technological solutions according to building layers, and tailoring analyses to specific building typologies or professional profiles. Indicative financial valuations might also be linked to adaptability levels. Finally, the current version of the tool does not account for material obsolescence, which represents an important dimension of long-term durability and, therefore, adaptability. Integrating this aspect would enhance the comprehensiveness of future iterations.

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## Appendix A

These appendices outline the drivers, trends and design actions integrated into the tool.

The validation of drivers, trends and actions constitutes an area for further research, which could be conducted through expert elicitation or extensive case-study analysis involving a large sample size.

**Table A1.** Driver and trend analysis in the default and case study scenarios.

| Group Factors | n. | Potential Drivers | Potential Trends | Default Scope | QM | N21 | TILA |
|---|---|---|---|---|---|---|---|
| S | 1 | Demographic shifts (urbanization, population growth/de-growth, migration trends, and gentrification) | Shrinking housing units, enlarging housing units, diffusion of co-housing and sharing practices, refurbishment for personal preferences, etc. | Y | Y | Y | Y |
| | 2 | Lifestyle change patterns (working and living arrangements, e.g., remote work and energy-intensive behaviours) | Convertible spaces (space for remote work), additional appliances and equipment, smart home integration, foldable partitions and furniture, etc. | Y | Y | Y | Y |
| | 3 | Public health concerns (readiness for pandemics, air quality demand, etc.) | Outdoor space (garden, balcony, etc.), convertible spaces, air ventilation/filtration systems (natural and mechanic), touchless systems, etc. | Y | N | Y | Y |
| | 4 | Public sustainability awareness (lower energy consumption, pollution, etc.) | Energy-efficient heating/cooling and lighting, energy efficient appliances, insulation and/or thermal mass, renewable energy systems (on-site), electrification, removal of oil/carbon/gas appliances, renovation of plumbing systems (water, gas, etc.), new use or replacement of envelope building elements, new use or replacement of services building elements, etc. | Y | N | Y | Y |

**Table A1.** *Cont.*

| Group Factors | n. | Potential Drivers | Potential Trends | Default Scope | QM | N21 | TILA |
|---|---|---|---|---|---|---|---|
| S | 5 | Ageing population | Adoption of (spatial) universal design requirements, shrinking housing units, diffusion of co-housing and sharing practices, age-friendly furniture and fittings, assistive technologies, etc. | Y | Y * | Y | Y |
| | 6 | Preference on housing unit size (expansion or contraction) | Shrinking housing units, enlarging housing units, diffusion of co-housing and sharing practices, reconfiguration of layout plans, additional guest rooms, etc. | Y | Y | Y | Y |
| | 7 | Change of user or household structure | Refurbishment for personal preferences, change in final use (e.g., residence to office), new use or replacement of services and building elements, new use or replacement of finishes and furniture, etc. | Y | Y | Y | Y |
| | 8 | Incoming guests | Additional guest rooms, Foldable partitions/screens and furniture, convertible spaces, etc. | Y | N * | N | N |
| | 9 | Emerging disabilities in the household | Adoption of (spatial) universal design requirements, etc. | Y | Y * | Y | Y |
| | 10 | Improved functional requirements (e.g., need for different kitchen or bathroom settings, etc.) | New use or replacement of services and building elements, new use or replacement of finishes and furniture, reconfiguration of layout plans, etc. | Y | Y | Y | Y |
| | 11 | Increasing indoor comfort (thermal, visual, acoustic, and air quality) | Energy-efficient heating/cooling and lighting, window replacement and sizing, insulation and/or thermal mass, new use or replacement of finishes and furniture, shading systems, etc. | Y | Y | Y | Y |
| | 12 | Aesthetic preferences (e.g., decoration) | New use or replacement of finishes and furniture, Reconfiguration of layout plans, etc. | Y | N | N | N |
| | 13 | Technological preferences (needs and wants) | Additional appliances and equipment (e.g., smart appliances), additional storage areas, etc. | Y | Y * | Y | Y |
| | 14 | Safety and security perceptions | Reinforced doors/windows, advanced surveillance systems, etc. | Y | Y | Y | Y |
| | 15 | Privacy | Soundproofing, shading systems, foldable partitions and furniture, etc. | Y | N | Y | Y |
| T | 16 | Innovations in construction and design processes (construction tools, off-site manufacturing, additive manufacturing, BIM, AI, etc.) | New use or replacement of envelope building elements (e.g., wall systems), new use or replacement of services and building elements, etc. | Y | N | Y | Y |

**Table A1.** *Cont.*

| Group Factors | n. | Potential Drivers | Potential Trends | Default Scope | QM | N21 | TILA |
|---|---|---|---|---|---|---|---|
| T | 17 | Changes in the supply chain (e.g., energy vector, materials, etc.) | Electrification, removal of oil/carbon/gas appliances, new use or replacement of envelope building elements, new use or replacement of services and building elements, new use or replacement of finishes and furniture, etc. | Y | Y | N * | N |
| | 18 | Innovations in building services and technologies | Energy-efficient heating/cooling and lighting, renovation of plumbing systems (water, gas, etc.), smart home integration (IoT, sensors, and actuators), renewable energy systems (on-site), etc. | Y | Y | Y | Y |
| | 19 | Regulatory and market demand for energy efficiency | Insulation and/or thermal mass, window replacement and sizing, shading systems (dynamic, etc.), energy-efficient heating/cooling and lighting, renewable energy systems (on-site), air ventilation/filtration systems (natural and mechanical), electrification, removal of oil/carbon/gas appliances, backup energy systems (battery storage, etc.), etc. | Y | Y | Y | Y |
| | 20 | Durability (need for repair, maintenance, etc.) | New use or replacement of envelope building elements, new use or replacement of services and building elements, new use or replacement of finishes and furniture, etc. | Y | Y | Y | Y |
| E | 21 | Housing-market trends (buyer/renter preferences) | Open spaces, enlarging room sizes, additional appliances and equipment (e.g., smart appliances), new use or replacement of services and building elements, new use or replacement of finishes and furniture, etc. | Y | Y | Y | Y |
| | 22 | Shifts in the labour market (automation, gig economy, and skill mismatches) | New use or replacement of services and building elements, new use or replacement of finishes and furniture, increased prefabrication of building elements, etc. | Y | N | Y | Y |
| | 23 | Entering the rental market (BnBs, etc.) | Refurbishment for personal preferences, reconfiguration of layout plans, new use or replacement of services and building elements, new use or replacement of finishes and furniture, etc. | Y | N * | N * | N |

**Table A1.** *Cont.*

| Group Factors | n. | Potential Drivers | Potential Trends | Default Scope | QM | N21 | TILA |
|---|---|---|---|---|---|---|---|
| E | 24 | Changes in households' financial capacity (due to inflation, stagnation of salaries, and economic crises) | Change in building ownership, decrease in indoor comfort, neglected maintenance of building elements, growth of rental demand and reduced purchase demand, shrinking housing units, diffusion of co-housing and sharing practices, etc. | Y | Y | Y | Y |
| | 25 | Intention to reduce living expenses (housing taxes, insurance, energy costs, and cost of technologies) | Shrinking housing units, diffusion of co-housing and sharing practices, window replacement and sizing, shading systems (dynamic, etc.), energy-efficient heating/cooling and lighting, renewable energy systems (on-site), etc. | Y | Y | Y | Y |
| | 26 | Presence of economic incentives | Higher maintenance, structural adaptation/resistance, adoption of (spatial) universal design requirements, insulation and/or thermal mass, window replacement and sizing, shading systems (dynamic, etc.), energy-efficient heating/cooling and lighting, renewable energy systems (on-site), air ventilation/filtration systems (natural and mechanical), electrification, removal of oil/carbon/gas appliances, backup energy systems (battery storage, etc.), etc. | Y | N | Y | Y |
| E | 27 | Climate hazards: temperature-related (heatwaves), water-related (flooding and droughts), wind-related (storms, etc.), and soil-related (landslides and erosion) | increased maintenance, storm-proof envelope building elements, elevated entrance, higher energy consumption, decrease in indoor comfort, insulation and/or thermal mass, window replacement and sizing, shading systems (dynamic, etc.), energy-efficient heating/cooling and lighting, renewable energy systems (on-site), air ventilation/filtration systems (natural and mechanical), electrification, removal of oil/carbon/gas appliances, backup energy systems (battery storage, etc.), etc. | Y | Y | Y | Y |
| | 28 | Other environmental hazards: earthquakes, fires, etc. | Structural adaptation/resistance, fire-resistant building elements, fire compartments, surveillance and alarm systems, etc. | Y | Y | Y | Y * |
| | 29 | Availability of natural resources (contraction of or increase in resources) | New use or replacement of envelope building elements, new use or replacement of finishes and furniture, etc. | Y | Y | N | N |

**Table A1.** *Cont.*

| Group Factors | n. | Potential Drivers | Potential Trends | Default Scope | QM | N21 | TILA |
|---|---|---|---|---|---|---|---|
| P | 30 | Political instability | Neglected maintenance of building elements, change in building ownership, change in final use, Building abandonment and under-use, surveillance and alarm systems, etc. | Y | N | N | N |
| | 31 | Active role of public institutions in the housing sector (funding and trading policies) | Growth of rental demand and lower purchase demand, higher maintenance, etc. | Y | Y | Y | Y |
| | 32 | Need to increase energy security and reduce consumption | Backup energy systems, insulation and/or thermal mass, window replacement and sizing, shading systems (dynamic, etc.), energy-efficient heating/cooling and lighting, renewable energy systems (on-site), etc. | Y | Y | Y | Y |
| | 33 | Regulatory framework (e.g., zoning regulation, fire safety, energy standards, mandatory services, accessibility regulations, etc.) | Energy-efficient heating/cooling and lighting, adoption of (spatial) universal design requirements, structural adaptation/resistance, fire-resistant building elements, etc. | Y | Y | Y | Y |

* Author changes of AI analysis output through Google research.

**Table A2.** Building Adaptability actions and performance levels.

| Design Action/Requirement | Adaptability Type | Performance Levels | | | |
|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 |
| Additional buildable area on the plot, with legal permission for horizontal or vertical (internal/external) GIA extensions | Scalable | <10% additional GIA | 10–30% additional GIA | 30–50% additional GIA | >50% additional GIA |
| Multiple vertical connections (stairs/lifts) or provision of space for additional vertical connections with external access in multi-storey buildings to accommodate layout changes or additional floors without loss of habitability | Versatile, Convertible, and Scalable | No space for vertical connections * or a single connection serving > 600 $m^2$ GIA per floor | Existing or easily addable vertical connections * (serving 600–400 $m^2$ GIA per floor) | Existing or easily addable vertical connections * (serving 400–200 $m^2$ GIA per floor) | Existing vertical connections in each building wing (serving <200 $m^2$ GIA per floor) |
| Pre-framed/pre-cut doorways and stairways to enable future building expansion (horizontal or vertical) | Versatile, Convertible, and Scalable | None | Pre-framed or easily implementable door/stairway opening; * on one building side (top included) | Pre-framed or existing door/stairway openings * on two building sides (top included) | Pre-framed or existing door/stairway openings * on three or more sides (top included) |

**Table A2.** *Cont.*

| Design Action/Requirement | Adaptability Type | Performance Levels | | | |
|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 |
| Structural capacity to accommodate future load increases and stresses (e.g., foundations, frames, and slabs). | Convertible and Scalable | 1.75 kN/m$^2$ | 2.5 kN/m$^2$ | 4 kN/m$^2$ | 5 kN/m$^2$ |
| Technical expandability and compatibility of the structural system with future adaptations without major structural works (e.g., pre-framed provisions such as strip foundations, etc.) | Scalable | None | Expandability on one side * | Expandability on two sides * | Expandability on three or more sides * |
| Presence of outdoor spaces supporting alternative uses or building expansion (garden, courtyard, terrace, loggia, balcony, etc.) | Versatile, Convertible, and Scalable | None | Balcony, Loggia * | Terrace (with or without balcony/loggia) | Private garden or courtyard (and, eventually, terrace, balcony/loggia, etc.) * |
| Degree of separation between load-bearing structure, façade, partitions and systems | Versatile, Refitable, Convertible, and Movable | <10% GIA without reversible connections | 10–50% GIA without reversible connections | 10–50% GIA with reversible connections | >50% GIA with reversible connections |
| Increased internal ceiling height | Refitable and Convertible | <2.60 m | 2.60–2.95 m | 2.95–3.40 m | >3.40 m |
| Regular and repetitive façade pattern enabling narrow bays for layout flexibility | Versatile and Convertible | >1.80 m | 1.80–1.35 m, with some bays over 1.80 m | 1.80–1.35 m, with some bays under 1.35 m | <1.35 m |
| Dismountability of building envelope (m$^2$ of facade surface) | Refitable, Scalable, and Movable | <20% | 20–50% | 50–90% | >90% |
| Adjustable/operable energy-efficient windows and shading devices | Adjustable | <10% (of total windows) | 10–30% (of total windows) | 30–80% (of total windows) | >80% (of total windows) |
| User-level control of HVAC, ventilation, and IoT systems | Adjustable | Centralized only | Occasional unit-level control | Frequent unit-level control | Always at unit level (sometimes at room level) |
| Reversible connections between material layers, enabling effective disassembly | Adjustable, Versatile, Refitable, Convertible, Scalable, and Movable | Mostly ‘wet’ or project-specific connections | Mostly difficult to disconnect | Occasional reversible connections | Mostly reversible connections |

**Table A2.** *Cont.*

| Design Action/Requirement | Adaptability Type | Performance Levels | | | |
|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 |
| Durable, disassemblable elements suitable for handling, transport, and reuse | Versatile, Refitable, Convertible, and Movable | Selected building elements; * cannot be easily dismounted, transported and reused at other sites | Only occasionally, selected building elements * can be easily dismounted, transported and reused at other sites | Several selected building elements * can be easily dismounted, transported and reused at other sites | Most or all selected building elements * can be easily dismounted, transported and reused at other sites |
| Fire resistance of load-bearing and separating elements (if not addressed by regulations) | Refitable and Convertible | >30 min | >60 min | >90 min | >120 min |
| Building insulation/thermal mass, albedo of surfaces, and acoustic performance of envelope and walls/slabs separating units | Refitable and Convertible | Does not meet current requirement | Meets current demand for current function only | Meets requirements for housing, offices, retail and care | Meets requirements for housing, offices, retail and care under the RCP 4.5 scenario |
| Capacity to increase insulation/thermal mass or acoustic performance in the future if current requirement is not met (e.g., deeper balconies, internal height, roof trusses, legal allowances, technical feasibility, etc.) [a] | Refitable | <20% of external envelope (roof, walls, and ground slab) | 20–50% of external envelope (roof, walls, and ground slab) | 50–90% of external envelope (roof, walls, and ground slab) | >90% of external envelope (roof, walls, and ground slab) or performance level 3 of action 16. |
| Multiple entrances per unit supporting internal flexibility | Versatile, Convertible, and Scalable | Single fixed entrance or served area exceeding 400 $m^2$ GIA per floor | Relocatable (single) entrance serving 400–200 $m^2$ GIA | Relocatable (single) entrance serving < 200 $m^2$ GIA | Multiple existing or pre-framed entrances serving < 200 $m^2$ GIA |
| Accessibility for disabled users (external and internal) | Versatile and Convertible | No current or future accessibility | No current accessibility (exterior and interior) but possibility to adapt | External accessibility only and possibility to adapt interiors | Full accessibility (exterior and interior) |
| Net building width and exposure | Versatile and Convertible | >15 m single exposure or length-to-width ratio < 1/3; >3 per unit | <15 m single exposure or 20–30 m with double exposure and length-to-width ratio > 1:3; <3 per unit | 15–20 m with double exposure and length-to-width ratio > 1:3; <3 per unit | <15 m with double exposure and length-to-width ratio > 1:3; <3 per unit |

**Table A2.** *Cont.*

| Design Action/Requirement | Adaptability Type | Performance Levels | | | |
|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 |
| Adoption of structural frame systems instead of load-bearing walls | Versatile, Convertible, and Scalable | <29 $m^2$ GIA not interrupted; * by load-bearing walls; load-bearing external walls | 29–65 $m^2$ GIA not interrupted * by load-bearing walls; Presence of load-bearing external walls | >65 $m^2$ GIA not interrupted * by load-bearing walls; absence of load-bearing external walls | Floor area not interrupted * by load-bearing walls; absence of load-bearing external walls |
| Span free of structural elements | Versatile, Convertible, and Scalable | None | <5.40 m | 5.40–8.10 m | >8.10 m |
| Undefined, neutral, or multifunctional rooms intended for future conversion | Versatile, Refitable, and Convertible | All rooms suitable for 1 function only (absent heavy renovation or refurbishment) | ≥2 rooms per unit suitable for two housing functions (e.g., bedroom, living room, studio, etc.) | ≥2 rooms per unit suitable for housing and non-housing uses | ≥3 rooms per unit suitable for multiple housing and non-housing uses |
| Removable or addable demising walls, enabling unit merging/splitting | Versatile, Convertible, and Scalable | Removable demising walls may enable units > 75 $m^2$; additional walls allow for subdivision of existing units (no size requirement). * | Removable demising walls may enable units between 75 and 150 $m^2$, and additional walls allow for subdivision into units below 75 $m^2$. * | Removable demising walls may enable units over 150 $m^2$, and additional walls allow for subdivision into units between 75 and 50 $m^2$. * | Removable demising walls may enable units over 150 $m^2$, and additional walls allow for subdivision into units under 50 $m^2$ * |
| Internal partitions enabling flexible reconfiguration | Versatile, Refitable, Convertible, and Movable | Internal partitions can be relocated through demolition and reconstruction with structural works | With demolition and reconstruction (with floor and ceiling works) in over 75% (m) of partitions and walls * | Easy disassembly and reconstruction (with minor floor and ceiling works) in over 75% (m) of partitions and walls * | Easy disassembly (with materials recovery) and reassembly (with minimal floor and ceiling works) in over 75% (m) of partitions and walls * |

**Table A2.** *Cont.*

| Design Action/Requirement | Adaptability Type | Performance Levels | | | |
|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 |
| Building service areas (e.g., bathrooms), wet zones (e.g., kitchens) and private vertical connections (e.g., stairs within units) located at the unit plan perimeter, allowing for flexibility of the layout plan | Versatile, Refitable, and Convertible | Mostly central and fixed location in the unit (unless structural works) | Mostly central location but possible relocation (without structural or heavy works) | Mostly lateral location but not possible relocation (unless structural or heavy works) | Mostly lateral location and possible relocation (without structural or heavy works) |
| Pre-laid piping and cabling for future installations (HVAC, plumbing, electrical systems, and Internet network systems). (Preparatory works) [a] | Versatile and Refitable | One among plumbing, electrical system or HVAC is missing and is not pre-laid | Plumbing and electrical systems are present, and HVAC is at least pre-laid (Internet network pre-laid or missing) | Plumbing, electrical systems and HVAC are present and pre-laid for potential upgrade of capacity (Internet network at least pre-laid) | All listed services are present and pre-laid for potential upgrade of capacity |
| Main water supply and discharge pipes ensure easy connection from any secondary plumbing line within the unit [a] | Versatile, Refitable, Convertible, and Scalable | Main supply/discharge pipes can be reached in <20% GIA * | Main supply/discharge pipes can be reached in 20–50% GIA * | Main supply/discharge pipes can be reached in 50–90% GIA * | Main supply/discharge pipes can be reached in >90% GIA * |
| Multiple attachment points for services and appliances (electrical outlets, plumbing, and HVAC terminal unit) | Adjustable, Versatile, Refitable, Convertible, and Scalable | Plumbing, electrical system or HVAC systems under requirements of performance level 1 | Units include $\leq$ 3 water supply and discharge points; HVAC is present in at least 50% of rooms over 9 m$^2$, and $\leq$3 electrical outlets are provided per room | Units include $\leq$ 3 water supply and discharge points, HVAC is present in at least 75% of rooms over 9 m$^2$, and $\leq$4 electrical outlets are provided per room | Units include $\geq$ 4 water supply and discharge points (kitchen, bathroom, washing machine, and extra), and in each room over 9 m$^2$, HVAC is present and $\geq$ 4 electrical outlets are provided * |
| Building technologies that allow for easy access and upgrades of services (e.g., raised floor, bulk screed and dry flooring, suspended ceilings, living walls, etc.) | Versatile, Refitable, Convertible, Scalable, and Movable | Most services mostly hardly or not accessible (e.g., concreted in) | Services mostly accessible with removal of materials with wet connections | Services mostly accessible with limited removal of materials with wet connections | Services mostly accessible (exposed services) or reversible connections |

**Table A2.** *Cont.*

| Design Action/Requirement | Adaptability Type | Performance Levels | | | |
|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 |
| Flexibility and accessibility of wiring and piping | Versatile, Refitable, Convertible, Scalable, and Movable | >90% * of wiring and piping can be considered rigid or unflexible without heavy works | 10–30% * of wiring and piping (easily accessible) can be replaced/moved/extended in a single floor/roof orientation (without wet/non-reversible connections) | 30–80% * of wiring and piping (easily accessible) can be replaced/moved/extended in different orientations (without wet/non-reversible connections) | >80% * of wiring and piping (easily accessible) can be moved/extended without replacement in different orientations (without wet/non-reversible connections) |
| Building services (HVAC and DHW) designed to allow for future capacity increase or building expansion with minor upgrades (Robustness of systems) | Refitable, Convertible, and Scalable | None | <10% power demand increase | 10–30% power demand increase | >30% power demand increase |
| Door openings that can be relocated within walls | Versatile | Single entrance to rooms but possibility to relocate in <10% of building rooms *. | Single entrance to rooms but possibility to relocate in 10–30% of building rooms *. | Single entrance to rooms but possibility to relocate in 30–80% of building rooms *. | Single entrance to rooms but possibility to relocate in >80% of building rooms *. |
| Prepared interior surfaces for the future installation of finishes (allowing for customization by end users) | Versatile and Refitable | <10% $m^2$ of interior finishes can be chosen by final user | 10–30% $m^2$ of interior finishes can be chosen by the final user | 30–80% $m^2$ of interior finishes can be chosen by the final user | >80% of interior finishes selected by the final user |
| Disassemblable/demountable internal and external finishes (tiles, cladding, etc.) to facilitate repair/replacement. | Versatile, Refitable, Convertible, and Movable | <10% $m^2$ of exterior and interior finishes may be replaced without demolition | 10–30% $m^2$ of exterior and interior finishes may be replaced without demolition | 30–80% $m^2$ of exterior and interior finishes may be replaced without demolition | >80% $m^2$ of exterior and interior finishes may be replaced without demolition |
| Dedicated space and equipment for remote work/study [a] | Convertible | No space without impeding regular room functions * (for other users) | Available space and equipment for <50% of unit users, without impeding regular room functions for other users | Available space and equipment for 50–80% of unit users, without impeding regular room functions for other users | Available space for over 80% of unit users, without impeding regular room functions for other users |

**Table A2.** *Cont.*

| Design Action/Requirement | Adaptability Type | Performance Levels | | | |
|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 |
| Movable, convertible, or adjustable furniture (e.g., for temporary room changes) | Adjustable, Versatile, Convertible, and Movable | No furniture can be moved/stored (tables, seats, beds, or storage furniture) | All furniture in <25% of rooms can be practically moved/stored (tables, seats, beds, and storage furniture) | All furniture in 25–75% of rooms can be practically moved/stored (tables, seats, beds, and storage furniture) | All furniture in >75% of rooms can be practically moved/stored (tables, seats, beds, and storage furniture) |
| Storage area for equipment, movable furniture or spare elements (e.g., tiles, etc.) | Adjustable, Versatile, and Convertible | No dedicated storage area * | Between 1 and 1.5 $m^2$ of storage area per 1-bedroom unit; 2–2.5 $m^2$ per 2-bedroom; 3–3.5 $m^2$ per 3+-bedroom | 1.5–2 $m^2$ per 1-bedroom unit; 2.5–3 $m^2$ per 2-bedroom; >3.5–4 $m^2$ per 3+-bedroom | >2 $m^2$ per 1-bedroom unit; >3 $m^2$ per 2-bedroom; >4 $m^2$ per 3+-bedroom |

Note: This list presents a selection of effective design actions/tactics. It is a compilation of possible actions proposed in the literature and case studies or [a] emerging from professional practices, not an exhaustive list. Specific requirements to provide further detail and performance level are then added, as provided from in literature and based on the authors' elaboration. * Asterisks identify notes within the tool to guide the calculation (not included in this annex). Performance levels are adapted from the 'Adaptive Capacity of buildings' tool, 'Flex 4.0', EN17680:2023 annex 3 and 'Level(s)'.

## References


1. UN-Habitat. *Priorities 2022–2023: Adequate Housing, Cities and Climate Change and Localising the Sustainable Development Goals*; UN-Habitat: Nairobi, Kenya, 2022.
2. Syed Jamaludin, S.Z.H.; Mahayuddin, S.A.; Hamid, S.H.A. Challenges of Integrating Affordable and Sustainable Housing in Malaysia. *IOP Conf. Ser. Earth Environ. Sci.* **2018**, *140*, 012001. [CrossRef]
3. OECD. *PH1.2 Housing Policy Objectives and Obstacles*; OECD: Paris, France, 2021.
4. Ram, P.; Needham, B. The provision of affordable housing in India: Are commercial developers interested? *Habitat Int.* **2016**, *55*, 100–108. [CrossRef]
5. Haidar, E.; Bahammam, A. An optimal model for housing projects according to the relative importance of affordability and sustainability criteria and their implementation impact on initial cost. *Sustain. Cities Soc.* **2021**, *64*, 102535. [CrossRef]
6. Wanyonyi, A.M.; Munala, G.; Alkhizim, A. Adoption of Green Neighbourhood Development: A Case of Affordable Housing Projects. *East Afr. J. Eng.* **2022**, *5*, 174–180. [CrossRef]
7. Carbone, C.; De Filippi, F.; Becchio, C.; Campagnaro, C. The benefits of building adaptability as a strategy for Sustainable Affordable Housing. In *Sustainable Built Environment Conference 2025 Zurich—Extended Abstracts; Shaping Tomorrow: Systems Thinking in the Built Environment*; ETH Zurich: Zurich, Switzerland, 2025.
8. BPIE. A Guidebook to European Buildings Efficiency: Key regulatory and policy developments. In *Report on the Evolution of the European Regulatory Framework for Buildings Efficiency*; BPIE: Brussels, Belgium, 2022.
9. *ISO 20887:2020*; Sustainability in Buildings and Civil Engineering Works—Design for Disassembly and Adaptability—Principles, Requirements and Guidance. ISO: Geneva, Switzerland, 2020.
10. Schmidt, R., III; Eguchi, T.; Austin, S.; Gibb, A. What is the meaning of adaptability in the building industry? In *Open and Sustainable Building*; Routledge: London, UK, 2010.
11. Pullen, S.; Zillante, G.; Arman, M.; Wilson, L.; Zuo, J.; Chileshe, N. *Ecocents Living: Affordable and Sustainable Housing for South Australia*; Department for Families and Communities, University of South Australia: Adelaide, Australia, 2009.
12. Araji, S.Z.; Shahin, B.R. Identification of Effective Integrated Indicators for Sustainable Affordable Housing Provision. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *856*, 012055. [CrossRef]
13. Schmidt, R., III. Designing for Adaptability in Architecture. Ph.D. Thesis, Loughborough University, Loughborough, UK, 2014.

14. Schmidt, R., III; Sanchez, V.K.; Austin, S. Evaluating the adaptability of an industrialized building using dependency structure matrices. *Constr. Manag. Econ.* **2014**, *32*, 160–182. [CrossRef]
15. AIA. *Buildings that Last: Design for Adaptability, Deconstruction, and Reuse*; AIA (American Institute of Architects): Washington, DC, USA, 2024.
16. Krystallis, I.; Rickaby, B.; Murtagh, N. A sustainable built environment for healthcare: Generative mechanisms for future-proofing. *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *297*, 012039. [CrossRef]
17. Georgiadou, M.C. Future-Proofed Energy Design Approaches for Achieving Low-Energy Homes: Enhancing the Code for Sustainable Homes. *Buildings* **2014**, *4*, 488–519. [CrossRef]
18. European Commission. *Horizon Europe—Design for Adaptability, Re-Use and Deconstruction of Buildings, in Line with the Principles of Circular Economy (Built4People Partnership)*; European Commission: Brussels, Belgium, 2024.
19. European Parliament. *EPBD—Energy Performance of Buildings (Recast)Amendments Adopted by the European Parliament on 14 March 2023 on the Proposal for a Directive of the European Parliament and of the Council on the Energy Performance of Buildings (Recast)*; European Parliament: Brussels, Belgium, 2021.
20. HM Government. *Strategy for Sustainable Construction*; Progress Report; HM Government: London, UK, 2009.
21. Mace, R.L. Universal design in housing. *Assist. Technol.* **1998**, *10*, 21–28. [CrossRef] [PubMed]
22. US Congress. *H.R.1158—Fair Housing Amendments Act of 1988*; US Congress: Washington, DC, USA, 1988.
23. *AS 4299-1995*; Australian Standard. Adaptable Housing. Standards Australia: Homebush, Australia, 1995.
24. Livable Housing Australia. *Livable Housing Design Guidelines*; Livable Housing Australia: Forest Lodge, Australia, 2017.
25. Department for Communities and Local Government. *Design of Lifetime Homes*; Department for Communities and Local Government: London, UK, 2012.
26. HM Government. *The Building Regulations 2010, Access to and Use of Buildings*; HM Government: London, UK, 2010.
27. Norwegian Building Authority. *Regulations on Technical Requirements for Construction Works*; Norwegian Building Authority: Oslo, Norway, 2017.
28. MLIT. Ministry of Land, Infrastructure, Transport and Tourism—Long-Term Quality Housing. 2024. Available online: https://www.mlit.go.jp/jutakukentiku/house/jutakukentiku_house_tk4_000006.html (accessed on 1 February 2026).
29. Kazunobu, M. The new Japanese housing policy and research and development to promote the longer life of housing. In *O&SB2010 "Open and Sustainable Building"*; Chica, Elguezabal, Meno & Amundarain, Eds.; Labein-TECNALIA: Derio, Spain, 2010.
30. Dodd, N.; Cordella, M.; Traverso, M.; Donatello, S. Level(s)—A common EU framework of core sustainability indicators for office and residential buildings. In *User Manual 1: Introduction to the Level(s) Common Framework, (Publication Version 1.0)*; Publications Office of the European Union: Luxembourg, 2020.
31. BREEAM. *BREEAM New Construction Residential*; Version 6.1; BREEAM: Watford, UK, 2025.
32. USGBC; LEED. *Reference Guide for Building Design and Construction*; V4; U.S. Green Building Council: Washington, DC, USA, 2016.
33. DGNB. *ECO2.1—Flexibility and Adaptability*; DGNB: Stuttgart, Germany, 2020.
34. DGBC. *Adaptive Capacity of Buildings, Supporting Document and User Instructions*; DGBC: The Hague, The Netherlands, 2021.
35. Geraedts, R.P.; Remøy, H.T.; Hermans, M.H.; Van Rijn, E. Adaptive Capacity Of Buildings; A determination method to promote flexible and sustainable construction. In *Architecture Otherwhere: International Union of Architects World Congress, UIA2014, Durban, South Africa*; UIA Durban: Durban, South Africa, 2014.
36. GRO. 2022. Available online: https://gro-tool.be/download-gro/ (accessed on 1 February 2026).
37. Becker, A.K.; Ross, B.E.; Albright, D. Evaluating The Weighted-Sum Approach For Measuring Buildings' Adaptability. *J. Green Build.* **2020**, *15*, 37–54. [CrossRef]
38. Maltese, S.; Kamara, J.; Dejaco, M.C.; Re Cecconi, F. Towards an Adaptability Rating for Buildings. In *Conference: Going North for Sustainability: Leveraging Knowledge and Innovation for Sustainable Construction and Development*; London South Bank University: London, UK, 2015.
39. Scialpi, G.; Declercq, J.; Gawlik, K.; Perrotti, D. Adaptability of buildings: To what extent do design-support models consider context-related factors? A literature review. *J. Phys. Conf. Ser.* **2023**, *2600*, 192009. [CrossRef]
40. Rockow, Z.; Ross, B.; Black, A.K. Review of methods for evaluating adaptability of buildings. *Int. J. Build. Pathol. Adapt.* **2019**, *37*, 273–287. [CrossRef]
41. Unver, H.; Alptekin, O.; Kalkan, M. Comparison of the building adaptability assessment models: A semi—Systematic review. *Int. J. Build. Pathol. Adapt.* **2022**, *42*, 982–1001. [CrossRef]
42. Yazdani, M.S.; Wilkinson, S. A Model for Assessing Adaptability in Heritage Buildings. *Int. J. Conserv. Sci.* **2021**, *12*, 87–104.
43. Andrade, J.; Braganca, L. Assessing buildings' adaptability at early design stages. *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *225*, 012012. [CrossRef]
44. Sibenik, G.; Sanchez, B.; Stouffs, R.; Herthogs, P. A literature review of measurement methods for building designs that enable higher-value resource recovery: The Circular Economy Potential framework. *Int. J. Sustain. Eng.* **2025**, *18*, 2573270. [CrossRef]

45. Taheriattar, R. Valuing Sustainability of Open Plan Buildings: A Case Study. *Int. J. Sustain. Constr. Eng. Technol.* **2021**, *12*, 1–14. [CrossRef]
46. Al Jameel, A.H.; Al Hafith, O.A. Investing the Concept of Courtyard for Sustainable Adaptable Multifamily Housing. *Am. Trans. Eng. Appl. Sci.* **2012**, *1*, 319–334.
47. Askar, R.; Braganca, L.; Gervasio, H. Design for Adaptability (DfA)—Frameworks and Assessment Models for Enhanced Circularity in Buildings. *Appl. Syst. Innov.* **2022**, *5*, 24. [CrossRef]
48. Da Fonseca Lamounieri, R.; Ferreira Saraiva, A.M.; De Freitas, R.R.; Morado Nascimeno, D. Adequacy level of Brazilian constructive systems to the Open Building: A research methodology. In *Open Building for Resilient Cities Conference*; Council on Open Building: Los Angeles, CA, USA, 2019.
49. Gupta, B.; Sibenik, G.; Herthogs, P.; Stouffs, R. Built Afterlife: A Web Tool for Exploring the Circular Potential of Buildings. In *12th International Conference on Industrial Ecology (ISIE 2025)*; ETH Zurich: Zurich, Switzerland, 2025.
50. March, A.; Rijal, Y.; Wilkinson, S.; Firidin Özgür, E. Measuring Building Adaptability and Street Vitality. *Plan. Pract. Res.* **2012**, *27*, 531–552. [CrossRef]
51. UNDP Regional Bureau for Asia and the Pacific. *Foresight Playbook; Overview of Foresight Tools*; UNDP Regional Bureau for Asia and the Pacific: New York, NY, USA, 2022.
52. Conway, M. *An Overview of Foresight Methodologies*; Thinking Futures: Palo Alto, CA, USA, 2008.
53. Georgiadou, M.C.; Hacking, T.; Guthrie, P. A conceptual framework for future-proofing the energy performance of buildings. *Energy Policy* **2012**, *47*, 145–155. [CrossRef]
54. Biro, A. How Can You Future-Proof Buildings? 2024. Available online: https://gbdmagazine.com/future-proof-buildings/ (accessed on 1 February 2026).
55. Clifford, W.C. Risk Assessment Using the Three Dimensions of Probability (Likelihood), Severity, and Level of Control. In *29th International Systems Safety Conference*; International System Safety Society: Las Vegas, CA, USA, 2011.
56. Schmidt, R., III; Austin, S. *Adaptable Architecture: Theory and Practice*; Routledge: Abingdon, UK, 2016.
57. Arge, K. Adaptable office buildings: Theory and practice. *Facilities* **2005**, *23*, 119–127. [CrossRef]
58. Dave, M.; Varshney, A.; Graham, P. Assessing The Climate Change Adaptability Of Buildings. In *Accarnsi Discussion Papernode 3—Built Environment, Innovation and Institutional Reform*; Faculty of the Built Environment: Sydney, Australia, 2012.
59. Kai, K.Y. *Adaptability and Flexibility in Architecture Concepts & Theories Applied in Residential Architecture to Achieve Adaptability*; Taylors University: Subang Jaya, Malaysia, 2022.
60. Heidrich, O.; Kamara, J.; Maltese, S.; Re Cecconi, F.; Dejaco, M.C. A critical review of the developments in building adaptability. *Int. J. Build. Pathol. Adapt.* **2017**, *35*, 284–303. [CrossRef]
61. Pinder, J.A.; Schmidt, R.; Austin, S.A.; Gibb, A.; Saker, J. What is meant by adaptability in buildings? *Facilities* **2017**, *35*, 2–20. [CrossRef]
62. Pinder, J.; Schmidt, R.; Gibb, A.; Saker, J. Exploring The Business Case For More Adaptable Buildings: Lessons from Case Studies. In Proceedings of the 2011 CIB Management and Innovation for a Sustainable Built Environment International Conference (MISBE 2011), Amsterdam, The Netherlands, 19–23 June 2011.
63. Estaji, H. A Review of Flexibility and Adaptability in Housing Design. *Int. J. Contemp. Archit.* **2017**, *4*, 37–49.
64. Danko, M.R. Designing Affordable Housing for Adaptability: Principles, Practices, & Application. Bachelor's Thesis, Pitzer College, Claremont, CA, USA, 2013.
65. Kuiri, L.; Leardini, P. Design for Adaptability and Disassembly: Towards Zero Construction Waste in the Australian Housing Sector. In *1st International e-Conference on Green & Safe Cities (IeGRESAFE), 20–21 September 2022*; Universiti Teknologi MARA, Perak: Perak Branch, Malaysia, 2022.
66. Dodd, N.; Donatello, S.; Cordella, M. Level(s)—A common EU framework of core sustainability indicators for office and residential buildings. In *User Manual 2: Setting up a Project to Use the Level(s) Common Framework (Publication Version 1.1)*; European Commission, Joint Research Centre: Brussels, Belgium, 2021.
67. RICS. *Whole Life Carbon Assessment for the Built Environment, Professional Standard, Global*, 2nd ed.; Royal Institution of Chartered Surveyors (RICS): London, UK, 2023.
68. Watt, H.; Davison, B.; Hodgson, P.; Kitching, C.; Tingley, D.D. What should an adaptable building look like? *Resour. Conserv. Recycl. Adv.* **2023**, *18*, 200158. [CrossRef]
69. Pushkar, S.; Shaviv, E. Using shearing layer concept to evaluate green rating systems. *Archit. Sci. Rev.* **2016**, *59*, 114–125. [CrossRef]
70. O'Hagan, A.; Buck, C.E.; Daneshkhah, A.; Eiser, J.R.; Garthwaite, P.H.; Jenkinson, D.J.; Oakley, J.E.; Rakow, T. *Uncertain Judgements; Eliciting Experts' Probabilities*; John Wiley & Sons Ltd.: Chichester, UK, 2006.
71. ICC. 2018 International Existing Building Code (IEBC), Chapter 6 Classification of Work. 2021. Available online: https://codes.iccsafe.org/content/IEBC2018P5/chapter-6-classification-of-work (accessed on 1 February 2026).
72. Noel, S. How Much Does It Cost to Remodel a House? 2025. Available online: https://homeguide.com/costs/house-remodeling-cost (accessed on 1 February 2026).

73. FRED. Average Sales Price of Houses Sold for the United States (ASPUS). 2025. Available online: https://fred.stlouisfed.org/series/ASPUS (accessed on 1 February 2026).
74. Hazen, T. How Much Does a Home Addition Cost? 2024. Available online: https://homeguide.com/costs/home-addition-cost (accessed on 1 February 2026).
75. Homekeep. The Truth About the Annual Cost of Home Maintenance. 2022. Available online: https://homekeep.com/learning-center/the-truth-about-the-annual-cost-of-home-maintenance/ (accessed on 1 February 2026).
76. HOA. How to Estimate Your Annual Home Maintenance Costs. 2024. Available online: https://www.homeownersassociation.com.au/how-to-estimate-your-annual-home-maintenance-costs/#: :text=Understanding%20the%20Basics,each%20year%20for%20maintenance%20expenses (accessed on 1 February 2026).
77. Hoffman, R. How Much Does It Cost to Rebuild a House? [2026 Data]. 2025. Available online: https://www.angi.com/articles/calculate-rebuild-costs-house.htm (accessed on 1 February 2026).
78. McFarland, D.; Ross, B.; Naser, M.Z.; Blok, R.; Teuffel, P. Quantitative evaluation of the relationship between physical parameters and building demolition or adaptation outcomes. *Archit. Struct. Constr.* **2021**, *3*, 415–428. [CrossRef]
79. Ozler, H.; Gucyeter, B. A Criteria- and Case Study-Based Approach to Evaluate Adaptability in Buildings. *Archit. Civ. Eng. Environ.* **2025**, *17*, 1–32. [CrossRef]
80. Mlote, S.D.; Budig, M.; Cheah, L. Adaptability of buildings: A systematic review of current research. *Front. Built Environ.* **2024**, *10*, 1376759. [CrossRef]
81. Firmino, R. Beyond the freedom to build: Long-term outcomes of Elemental's incremental housing in Quinta Monroy. *Urbe Rev. Bras. Gest. Urbana* **2021**, *13*, e20200001. [CrossRef]
82. Dodd, N.; Cordella, M.; Traverso, M.; Donatello, S. Level(s)—A common EU framework of core sustainability indicators for office and residential buildings. In *User Manual 2: Setting up a Project to Use the Level(s) Common Framework (Publication Version 1.0)*; JRC Technical Reports; Publications Office of the European Union: Luxembourg, 2020.
83. Cuperus, Y. An Introduction to Open Building. In *9th Annual Conference of the International Group for Lean Construction, Singapore, Singapore*; Ballard, G., Chua, D., Eds.; National University of Singapore: Singapore, 2001.