Adaptability of buildings: to what extent do design-support models consider context-related factors? A literature review

Adaptability of buildings: to what extent do design-support models consider context-related factors? A literature review

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A growing interest for the adaptability of buildings has been expressed in the last years when talking about circular economy. The adaptability of a building indicates its ability to evolve and host different functions all along its life cycle with the minimum generation of waste. However, design-support models for adaptable buildings are still in development and they do not always include context-related factors on a local or large scale, such as data about building stock, socio-economic trends, policies, and regulations. This paper aims to provide an updated review of the existing design-support models and a critical reflection on their links to local contexts, to finally contribute to the research question: "to what extent the design-support models for adaptability consider context-related factors?". A literature review was conducted using Scopus, including peer-reviewed journal papers, conference papers and books. The research provides an updated state of the art of the existing models to analyse and rate the adaptability of buildings with a special focus on the indicators that considers context-related factors. A series of recommendations are proposed to consider context-related factors with an impact on building adaptability, to facilitate the implementation of adaptability models to local contexts and to identify the barriers to such an adaptation. Finally, this paper aims to set the basis for future research on design-support models and their integration in a more context-related and accessible design workflow.

1. Introduction

The evolution of technology, the challenge of climate change and global health are influential factors in the construction sector, inducing changes that cannot be easily predicted [1]. Designing buildings that are able to face changes and to be adapted during their life span, is an important prerequisite for a more sustainable and circular construction [2]. An adaptable design will be able to handle issues of obsolescence and extend the useful life of the building and its components. This approach has a great synergy with the circular economy strategies to minimize the consumption of raw resources and energy inputs and to reduce waste [3]. Thereby the design for adaptation and materials recovery is becoming increasingly interesting for academics and practitioners [4]. Among the growing body of literature about the "building adaptation" concept and the related indicators, this article takes the following definition as a starting point: "adaptation is the capacity of a building to accommodate effectively the evolving demands of its users and the context, thus maximizing its value through life" [5].

This definition sheds light on the significance of the context, which includes the social, economic and environmental aspects of building's surroundings, such as the building codes, the climate and the historic preservation requirements [1]. According to Kamara et al. [6], these context-related factors are

stronger triggers for change than building-related factors, inducing a transformation even before the physical building elements have reached their expected lifespan. Since a greater understanding of the impact of context-related factors would enhance our capacity to design adaptable buildings, this article aims to analyze the existing assessment models to understand to what extent these factors are taken into consideration. This study builds on the recognition that the building context has a great impact on building adaptability and aims to contribute to the research question: "to what extent the design-support models for adaptability consider context-related factors?". To investigate this research question, a review of the existing adaptability assessment models was performed with the following objectives: 1. A state of the art of the existent building adaptability models; 2. A comparative analysis of their main developer (academia or practice); domain of analysis (existing or new buildings); uses assessed (offices, housing etc.) and whether if the assessment is for a cross-use or in-use adaptability (changing the use of the building or not); factors assessed (building-related or context-related) and data collection methods (survey, case studies, literature review etc.); 3. An identification of barriers for the implementation of these models. The article is structured as follows: a state of the art of the building adaptability concept and of context-related factors included in assessment models is outlined; the materials and methods used to perform the review are then presented, followed by a discussion of the results and outlook for future research.

2. State-of-the art

1.1. The concept of building adaptability and its nuances

In built environment research and practice, the concept of "adaptability" is used in a diverse way. This is mainly due to the great diversity of disciplines, types and frequency of change occurring in the building and building types addressed under this umbrella topic. An unclear definition of adaptability can lead to a misunderstanding of the adaptations required and results into an inappropriate design strategy [7]. There is a broad body of literature on adaptability and its meanings. [8], [9], [7], and [10] among others, analyse the multiplicity of terms that are used as either synonyms, antonyms or metaphors by the practitioners. This article employs the categorization proposed by [11] to clarify the use of these terms. Different categories of adaptability are set according to the type and frequency of changes occurring in the building: 1. generality/multifunctionality/versatility (frequent changes without a modification of the building's properties); 2. flexibility/adjustability (changes with a moderate and low frequency affecting the properties of the building); 3. elasticity/expandability/scalability (changes with low frequency that allow the building to be extended). This categorization introduces another important dimension in building adaptability: the time of the change, which can be cyclical (frequency) or linear (short or long term). The time factor is pivotal for change, allowing to perceive the building as a dynamic system able to react to emerging needs [12]. Following the review in [13] and as echoed in the definition of adaptability provided above, the ability to respond to change over time is a key characteristic of adaptability [14], where change is meant to be an alteration to the project's program or aspects caused by modifications to pre-existing conditions, assumptions or requirements [15] induced by context-related or building-related factors.

1.2. The context-related factors and the building obsolescence

Building are expected to be adapted during their lifecycle [10], a building that responds to the stakeholders'(e.g. users, tenants and community) needs is considered as relevant. By contrast, a building that cannot meet changing performance requirements is considered as obsolete [16]. Performance means the ability of a building to provide the service for which it has been designed and depends on a wide range of factors [16] that can be classified into the categories suggested by [17]: 1. physical (e.g. structure integrity, materials durability and maintenance); 2. economic (e.g. density, site's features, transport facilities); 3. functional (e.g. structural grid, free height, disassembly potential, services net); 4. technological (e.g. orientation, insulation, natural lighting); 5. social (e.g. history, aesthetics, neighbourhood); 6. legal (e.g. safety, security, disability access); and 7. political (e.g. ecological footprint, masterplan, community support). Physical, functional and technological are building-related

factors, while economic, social, legal and political are context-related. According to [6], changes are induced more by context-related factors than building-related ones, proving the interest and the importance of including those into the adaptability models.

3. Materials and methods

A literature review was conducted from the database and search engine Scopus, to achieve the three research objectives presented above. Peer-reviewed journal papers, conference papers and books were included in the search. In the databases, a Boolean operator was applied to combine interrelated key words in one search query, including the terms: "building adaptability" AND "model" OR "framework". The search was conducted between September 2022 and April 2023. The sources have been selected covering a period from 1990 to 2023. To achieve the first objective, a first screening of the results has been done in order to identify the literature reviews on the topic and the sources related to a specific model. The literature reviews have been classified in a chronological way, highlighting the models reviewed. To achieve the second objective, the reference lists of the literature reviews has been taken as basis for a second round of research, which has been carried out to cover all the sources related to specific adaptability models and frameworks. The results have been organised to enable a comparative analysis of these models. Finally, the models' data sources and methods have been explored to accomplish the third objective and identify where possible, the limits to the application of those models in local contexts.

4. Results and discussions

The literature review resulted in nine reviews on building adaptability, published between 2008 and 2022. In seven of these reviews, several models evaluating the adaptability of different building typologies have been discussed. The models with the higher scientific impact, are presented in the matrix below (Figure 1) and classified chronologically according to: their main developer (academia or practice); their domain of analysis (existing or new buildings); the uses assessed (offices, housing etc.) and whether if the assessment is for a cross-use or in-use adaptability (changing the use of the building or not); the factors assessed (building-related or context-related); the data collection methods (survey, case studies, literature review etc.) and the validation system (case studies, database, inter-model comparison, no validation).

The models analysed are : 1) Adaptive Reuse Potential (ARP) [20] which is based on a formula to evaluate to what extent obsolescence factors would reduce the useful life of a building; 2) Adaptable Building Design (ABD) framework [21] which examines the adaptability of a building in the light of future uncertainties such as market conditions; 3) iconCUR [22] a conceptual framework to assess the building obsolescence to understand the potential adaptability of a building; 4) adaptSTAR [23] a star-based scoring checklist which considers both building related and context-related factors; 5) Causal Loop Diagram of building adaptation (CLD) [14] a graphical model representing the different variables in a system to describe building adaptation; 6) Preliminary Assessment Adaptation Model (PAAM) a checklist to assess in-use adaptations [24]; 7) Flex 4.0 [25] a set of indicators considering both building related and context-related factors; 8) Triple-bottom-line retrofit optimization [26] a system to evaluate the benefits of different type and levels of adaptation; 9) Learning Building Framework (LBF) [27] a quantitative framework to orient new designs with a set of weighted criteria based on cost of operation and probability of adaptation; 10) Conversion meter [28] a series of checklists progressively more detailed, to place the building in its context up to an analysis of financial feasibility and risk assessment; 11) Transformation capacity tool (TCT) [29] a set of rules to assess the building adaptability based on building-related factors; 12) Spatial Assessment of Generality and Adaptability (SAGA) [30] a method to compare the adaptability of different spatial layouts and 13) Adaptive Reuse Assessment Model (ARAM) [31] focusing on the adaptive reuse and adaptation potential of heritage buildings. The highest scientific impact is held by ARP and adaptSTAR, which have been cited in five of the nine reviews selected; IconCUR and CLD have been cited in three reviews, followed by PAAM, Flex 4.0. and SAGA cited in two reviews. Almost all the models are developed in an academic environment and do not have

any connection in a Building Information Modelling (BIM) or other computer-aided design tools thus revealing a lack of integration in the practitioners' workflow. Moreover, such information technologies would provide a platform to enhance the concept of adaptability in new and existing buildings thanks to their potential to connect datasets to the building model [14]. The lack of model assessing new designs has also been found by [3]. This means that current models help to decide between end-of-life options (adaptation or demolition), while designing for adaptability in new buildings would consider all the lifecycle. Another shortcoming of the existing models is the assessment of uses such as healthcare, while they are more oriented to assess generic uses (general) or offices and commercial ones. Moreover, they do not focus on the consequences of a radical use shift (cross-use) and neither on an in-use adaptability, for which introducing temporal variability would be an essential step forward (e.g. healthcare structures having to face short-term adaptations). Regarding the building-related and context-related factors, most of the models consider both factors. However, some of them (e.g. LBF, SAGA and TCT) mainly focus on building-related characteristics. The building-related factors are often project-based and thus easier to review, while context-related factors are mainly fed by literature reviews or case studies analysis. Only a few models base their evaluation criteria on data issued from government statistics and market analysis (ABD and triple-bottom line retrofit optimisation); and only in one case (PAAM) a large dataset based on government statistics has been created. The analysis of market demand and building stock can help to understand which kind of adaptation should be provided and at what time. For instance, the ABD

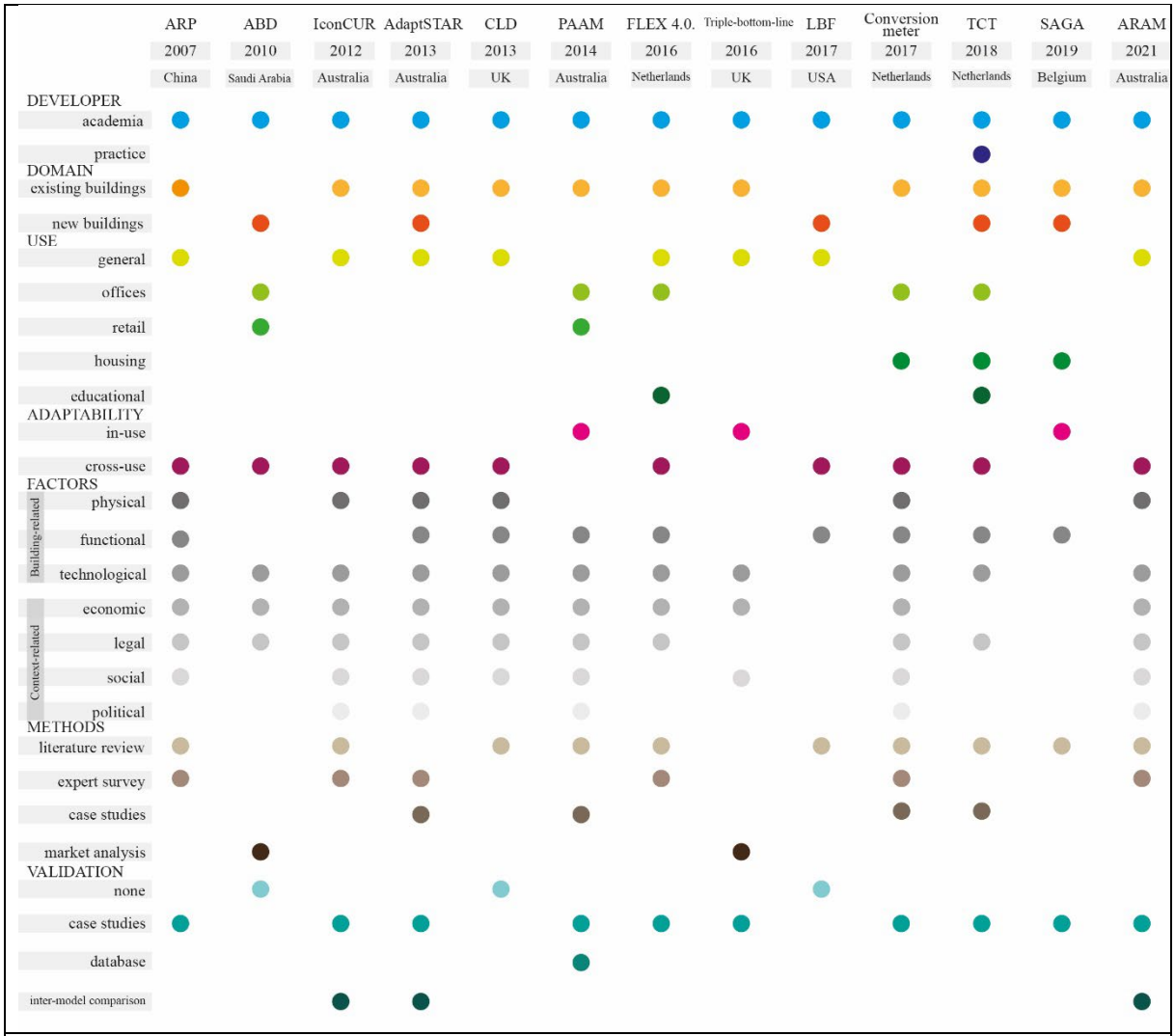

Figure 1. Matrix of results

model was applied to a case study of a commercial building to choose if, based on the demand projection chart for offices and retails, an expansion or a cross-use adaptation (e.g. from office to retail or vice-versa) would be more suitable.

Such models, able to measure adaptability and its costs, could enhance the setting of financial incentives from policy in this field [14]. The results suggest that adaptability assessment should be a multi-criteria decision analysis fed by empirical socio-economical data, environmental data and/or technical specification data. In particular economic data would provide a cost-benefit analysis to support the decision making process [14]. Unfortunately, most data on costs are based on new-built projects, while less cost-benefit information is available on conversion projects. Probably because conversion costs are highly project-related and building element-related [28]. The difficulty to collect data is understandable but it could be overcome with stakeholders' involvement and policy-support. The AdaptSTAR model adopts an innovative methodology mixing case studies analysis and stakeholders' perspective to feed the selection of design criteria and to define their importance while attributing a 'weight' to each of them. Unlike other models, the criteria are not only weighted, but a correlation is established among them. As stated in [1], some of the models have not been validated yet and others have been validated through intra-models comparisons or comparison with a limited amount of case studies. This proves the difficulty to retrieve data to inform the adaptability factors and to validate the model on a larger scale. The geolocation of each model has also been provided in table 1 to raise the question of the data origin. Factors such as legal, social, political and economic are so context-related that the same model would require strong adaptation to meet the requirements of another country.

5. Conclusions and outlook

To cope with environmental, social and economic sustainability agendas and their uncertainties, buildings need to be highly adaptable to easily respond to the changing requirements without knowing what these will be [14]. According to [4], adaptability strategies are normally defined in relation to physical, functional and technological characteristics, but it is becoming clearer that the concept of adaptability is not only related to changes in the building fabric, but also to stakeholders' actions and needs [7]. In his review, Heidrich et al. [4] clarifies that adaptability cannot be limited to the design of multipurpose rooms or movable walls. It should also involve the building's surroundings and take the stakeholders' perspectives into account. Nevertheless, building adaptability is a complex process that involves many stakeholders and relies on multi-dimensional data regarding building-related and context-related factors. The overall conclusion of the study is that the existing building adaptability models stay in an academic context and none of them have yet been tested on a large number of projects. Almost all of them do not integrate updated data on building stocks, market demand or costs, while evidence has been found in the literature about the crucial importance of datasets in the development of building adaptability models [1]. Building adaptability should not be considered as a stand-alone topic, but instead connected with a cost-benefit analysis and an overview of the building performance all along this life cycle [4]. Moreover, more efficient adaptability would be achieved if the link between adaptability and circularity is enhanced, [4] and if policies aimed at the collection, management and adaptability of these data would be implemented. Further research should be done to integrate these models into the existing information technologies such as BIM, which could help with the management of data about the building-related factors and to improve interoperability of adaptability and building design models, making it easier to test and validate different design options.

6. References

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