DOI: 10.53469/jpce.2025.07(11).01

A Framework for Early-Stage Design Assessment: Integrating Adaptability and Resilience Metrics to Mitigate Building Obsolescence

Jitvin Beri[1], Priyanka Gupta[2]

[1]Assistant Professor, Sinhgad College of Architecture, Pune
jitvin@sinhgad.edu

[2]Visiting Faculty, Bhanuben Nanavati College of Architecture, Pune and Practicing Architect
priyanka@bnca.ac.in

Abstract: ***Building infrastructure and construction is essential to India's rapidly growing economy; in the near future, it is anticipated that approximately 700–900 million square meters of commercial and residential space will need to be built. The Ministry of Housing and Urban Affairs states that estimates indicate the construction industry contributes significantly to India's carbon footprint, creating between 150 and 500 million tonnes of construction and demolition (C&D) polluting waste annually and cannot be managed. Lack of adaptability in the building design program is a major cause of demolition and premature end - of - life stages. In this scenario, there is heightened concern regarding the drastic environmental degradation that could result from failing to prioritise the implementation of sustainable practices from the outset of design and decision - making. In the Life Cycle Assessment (LCA) process, flexibility and adaptability are given immense significance in any project design. This paper highlights the current research gap of unavailability of environmental indicators 'measure' aspects such as adaptability and/or flexibility, durability, robustness or resilience. However, these aspects affect the duration of the working life of the building and are therefore, extremely relevant for the minimization of waste and optimisation of the use of resources. Hence, the framework for the assessment of the environmental indicators should take this into consideration from early design stage. Flexibility and adaptability enable buildings to recycle, re - use and upcycle these buildings into urban regeneration projects, and these factors need to be included in the early design stage, and ethos of architectural practice, effectively proving sustainable.***

Keywords: Adaptability, Resilience, Early Design Stage, End - of - life stage

1. Introduction

Impact of Architectural Project stages and Indian scenario:

An Architectural Project is an extensively drawn - out process from its inception through to completion. There are various external influences, internal elements, regulations and forces to be considered by the design team. Projects are collaborative efforts of individuals of various capabilities according to tasks and processes, who need to work in sync to accurately execute the designs.

In India, there are no definite recognized plans of work or prescribed procedures and regulated design thinking processes that design firms must follow when developing architectural projects unlike RIBA (U. K.) which has been developed much since 2020. However, the architectural profession has a well - developed phase - by - phase schematic that is universally acknowledged.

The framework of stages can be summarized as follows:

These steps are closely interlinked and produce pre - requisite information for every next step. Architects may or may not be involved in the entire process, but play a pivotal role in design problem - seeking and problem - solving throughout the process and have to deeply think about sustainability and the future of the project owing to the impact of their decisions at every stage and current climate predicament. The decisions of the design team, affect every stage of the project and the building's performance, life cycle and environmental impact. Hence, a long - term perspective has to be included in this entire process and principles of adaptability and resilience have to be founding factors of early design stages, to influence the outcomes. The conventional design and construction practices which do not cope with these principles lead to decisions of premature demolition of buildings.

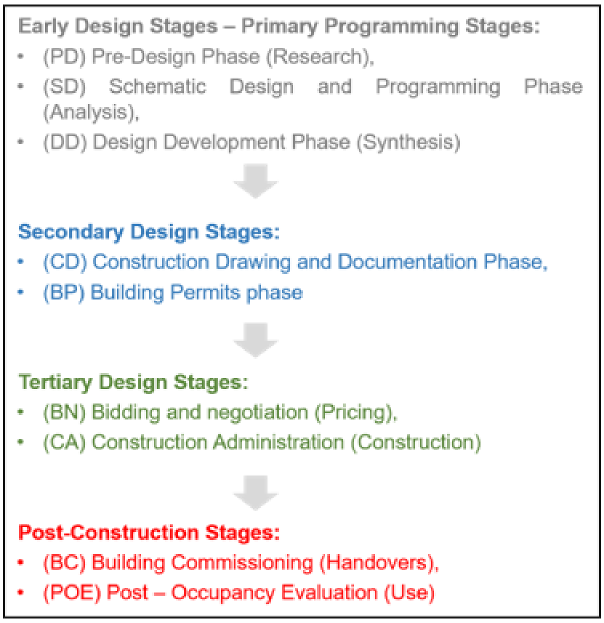

Figure 1: The phase - by - phase schematic framework of stages of a generic architectural project

Life Cycle Assessment (LCA) of a construction project can provide valuable information on the environmental performance of the building, but it faces several challenges, like multiple sources involved in data collection, irregularities in quality of data, scope and validation procedures, complexity of design models and interactions of various components, uncertainty of scenarios, interests of various stakeholders and cost involved.

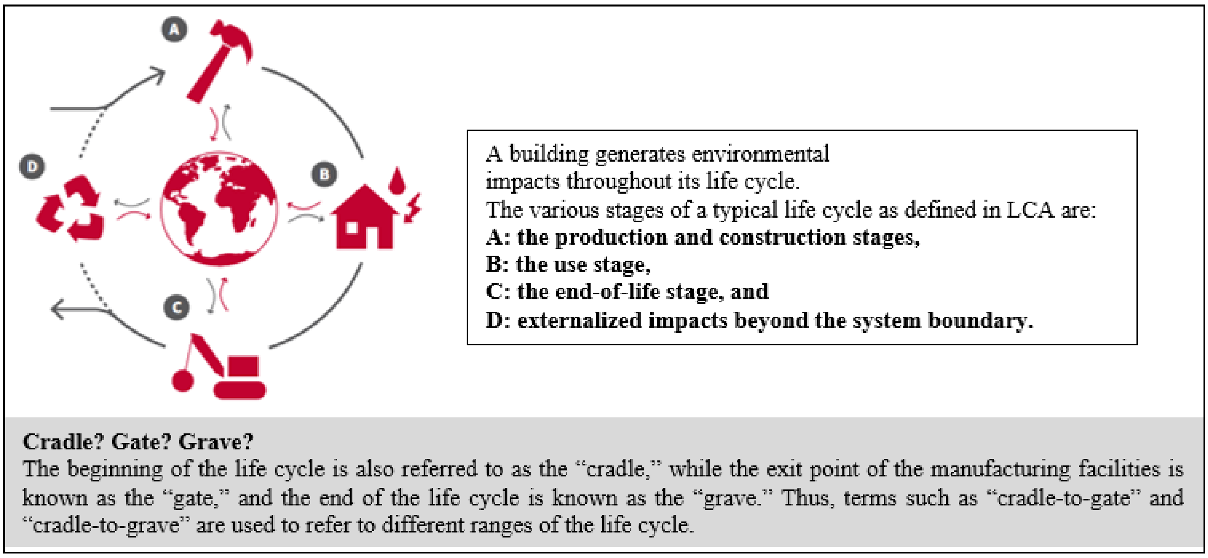

Figure 2: Life Cycle Assessment stages of a building
Source: Life Cycle Assessment of Buildings: A Practice Guide Published by: The Carbon Leadership Forum

Preventive considerations can help mitigate uncertainties in the scenarios of building life span.

"Future preservation means that the building is not only built to last, but … has the freedom to adjust and even its ability to change directions, is entirely preserved."
- Shearing layers of Change (Brand, S.1994)

There is currently no single industry source of reference for embedding adaptability and resilience into programme delivery that can be understood and applied by all built environment professionals, from clients to operators, and hence there is a research gap in identifying indicators for adaptability and resilience which can be overplayed to provide insight and best practice content to the design team.

Need for Research
Building infrastructure and construction is essential to India's rapidly growing economy. Soon, by 2050, it is anticipated that approximately 700 – 900 million square meters of commercial and residential space will need to be built. The Ministry of Housing and Urban Affairs states that estimates indicate the construction industry contributes significantly to India's carbon footprint, creating between 150 and 500 million tonnes of construction and demolition (C&D) polluting waste annually. Construction and demolition waste is one of the largest solid waste streams in the world. This brings many challenges to the forefront such as unauthorized dumping, a lack of space for disposal, reregulated recycling and improper mixing with biodegradable waste causing unbearable load on the environment later.

Therefore, thoughtful considerations of the adaptability and resilience dimension in design, extending life expectancy and reusing existing and in - design buildings can spare the embodied energy and decrease their life cycle and environmental impact. These considerations in early design stages allow the designer to have high influence at low expenditure according to the *Level of Influence Curve* by Boyd Paulson (1976).

From the study of influences early design stages prove genuine value providing stage with high influence at low expenditure.
This research aims to develop a framework to consider adaptability in early design stages, by the architects to reduce the impact on the end - of - life of the buildings, where architects have low influence.

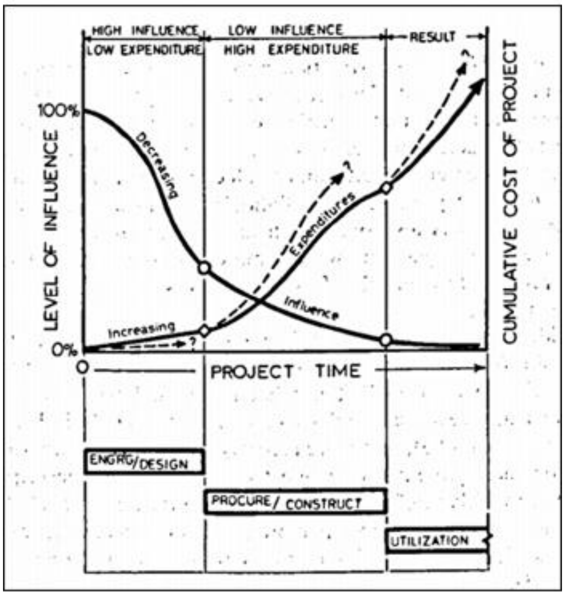

Figure 3: The Original Level of Influence on Project Costs Curve by Boyd Paulson, 1976.
Which later formed the foundation for HOK's MacLeamy Curve in 2004.

The objectives of this paper are:

- Develop ways to address adaptability in early design stage of architecture,
- Identify drivers and design strategies in the field, and
- To define important aspects of the context for the framework.
- Identify indicators and calculation procedures to describe it.

2. Research Methodology

Following the research objectives, work presented in this research study is undertaken, as an attempt, to develop a decision - making support tool for designers, which can be overlayed on the existing design process workflow to improve the inclusion of adaptability and resilience parameters in early design stages. Such a tool development will be based on a multi - dimensional approach.

1) Study of concepts in building life cycle assessment (LCA), architectural design process frameworks, project phases, and Environmental Impact Analysis (EIA);
2) Literature review of research papers and books to understand dimensions of adaptability in architectural design.
3) Analysis of existing building sustainability analysis (BSA) methods and degree of considerations for adaptability and resilience.
4) Questionnaires surveys and structured interviews
5) Data collection
6) Framework proposal
7) Validation

The decision to include adaptability and resiliency in early design phases of design decision - making arose from steps (i), (ii) and (iii). Indicators for adaptability and resiliency were identified in steps (iv) and (v) through a questionnaire survey of designers, construction managers, operators, promoters and users. This further corroborated those architects' consideration of these pertinent factors as relevant, mentioning the lack of framework and motivation from some other external factors or stakeholders to include these factors. Steps (vi) and (vii) helped establish adaptability and resilience indicators and propose an overlay to the existing design process, and guidelines to promote thinking.

1) Adaptable Architecture: Strategies and Dimensions: Adaptability is often used in design briefs and building design in general. Due to its popularity, adaptation and adaptable architecture are umbrella terms for many different strategies and principles and therefore the term adaptability has been described as a fluid concept heavily influenced by its context which can lead to confusion in practice. Hence determining the context which led to the adoption of different strategies could highlight why certain strategies were adopted over others. Furthermore, the context connects adaptability, the built environment and the global challenges.

The Intergovernmental Panel on Climate Change (IPCC) suggests two main approaches to tackle climate change: adaptation and mitigation. The IPCC defines adaptation as "the adjustment in natural or human systems in response to actual or expected stimuli or their effect, which moderates harm or exploit beneficial opportunities" [28] (p.982) and mitigation as "an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases" (p.990). Although mitigation addresses most of our long term problems, adaptation strategies are believed to also enhance the built environment's resilience to said challenges.

Adaptability is often considered within building sustainability assessment (BSA) methods by

1) ease of disassembly and deconstruction,
2) spatial structure,
3) indoor height clearance, accessibility of utility cables and conducts and,
4) modularity, especially for office buildings (Bragança et al., 2016).

However, the international standards as ISO 21929 - 1: 2011 and EN 16309: 2014, recommend addressing adaptability also through: (i) individual users, (ii) change of user, (iii) technical aspects and, (iv) change of use (ISO, 2011; CEN, 2014).
EN 16309: 2014 stated the following as measures to evaluate the adaptability potential of a building:

1) Minimisation of internal load - bearing - elements (columns, internal walls);
2) Ease of demolition/demountability of internal building elements;
3) Redundancy in load - bearing capacity;
4) Accessibility/demountability of pipes and cables;
5) Provision of space for additional pipes and cables required for a change of use;
6) Provisions for possible future equipment (e. g. elevators).

Subsequent literature analysis to study the adaptability dimensions, interrelationships and strategies concerning their occurrence under three pillars of sustainability as main drivers behind the research are reviewed and noted in **Table [1]**

	Literature on Adaptable Architecture			Three Pillars of Sustainability		
Year	Main Drivers for Adaptable Architecture	Adaptability Strategies	Adaptability Dimensions	Social	Environmental	Economical
1963	Olgyay, 1963 [4]	Bioclimatic	responsive, adjustable, versatile, convertible	1	1	0
1972	Habraken, 1972 [5]	Open building	adjustable, flexible, refitable, convertible, scalable	1	0	0
2012	Gamage and Hyde, 2012 [6]	Biomimicry	n.s. systems thinking	0	1	1
2012	Cole, 2012 [7]	Regenerative design	n.s. systems thinking	1	1	0
2013	Roaf, Fuentes and Thomas-Rees, 2013 [8]	Adaptive comfort	adjustable, versatile, refitable, convertible	1	1	0

2013	Taleghani, Tenpierik, Kurvers, and van den Dobbelsteen, 2013 [9]	Zero energy, Adaptive comfort	not specified (n.s.)	1	1	0
2013	Loonen et al., 2013 [10]	Interactive tech	all dimensions	1	1	1
2014	Du, Bokel and van den Dobbelsteen, 2014 [11]	Adaptive comfort, Bioclimatic	adjustable, flexible	1	1	0
2014	Kasinalis et al., 2014 [12]	Interactive tech	responsive	1	1	0
2014	Schalk, 2014 [13]	Metabolist	adjustability, versatile, refitable, convertible, scalable; also: systems thinking	1	0	0
2015	Vellinga, 2015 [14]	Vernacular	all	1	0	1
2015	Holstov, Bridgens and Farmer, 2015 [15]	Passive	responsive	0	1	0
2015	L'opez et al., 2015 [16]	Biomimetics	responsive	0	1	0
2016	Alders, 2016 [17]	Adaptive comfort	adjustable, versatile	1	1	0
2016	Minami, 2016 [18]	Open building	adjustable, flexible, refitable	1	1	0
2017	Holstov, Farmer and Bridgens, 2017 [19]	Passive	Responsive	1	1	0
2017	L'opez et al., 2017 [20]	Biomimetics	Responsive	1	1	0
2017	Orden van, 2017 [21]	Tiny House	adjustable, versatile	1	0	0
2019	Tabadkani et al., 2019 [22]	Adaptive comfort, Interactive tech	responsive / dynamic	1	1	0
2019	Crespi and Persiani, 2019 [23]	Interactive tech, zero energy	responsive / dynamic	0	1	0
2019	Watson, 2019 [24]	Bioinspiration	responsive, flexible, movable	1	1	0
2019	Rasmussen, Birkved and Birgisd'ottir, 2019 [25]	Design for Disassembly (DfD), Circular Economy (CE)	scalable, movable	0	1	1
2019	Geldermans, Tenpierik and Luscuere, 2019 [26]	Circ-Flex	adjustable, flexible	1	1	0
2019	Zarzycki and Decker, 2019 [27]	all	responsive, refit-able, convertible	0	1	0
			Totals:	18	19	6
Study of Adaptability Dimensions						
2013	Gosling et al. 2013 [1]	–	adjustable, flexible, refitable	1	1	1
2016	Schmidt III and Austin, 2016 [2]	multiple	all	1	1	1
2017	Heidrich et al., 2017 [3]	multiple	all	1	1	0
			Total	3	3	2

In Heidrich et al [29], the context comprises the socioeconomic processes, sustainable development, and climate change. This clarification could be considered a pleonasm as others define sustainable development as the sum of economic, social, and environmental aspects [30]; known as the three pillars of sustainability [31]. While the term sustainability implies an element of thinking about the future, it seems necessary to implicitly add time as an integral dimension of the context as this dimension is often lacking in adaptability definitions.

2) Framework for adaptable architecture:

Adaptability Design allows renovation and repurposing of buildings through adaptive reuse and capitalizes on previous human capital, significantly saving material and embodied energy invested, allowing more resources for future generations.

Resilient Sustainable Design looks for ways to mitigate the effects of nature and provide human safety while conserving ecological and human resources.

Taking what is already there and acknowledging its value through deliberate considerations of these factors in early design stages we can promote sustainability on the multiple levels of the Quadruple Bottom Line (QBL) as follows:

- **People:** The built environment reflects our core values and cultural heritage, and this is very important for social cohesion and a sense of belonging.
- **Planet:** By evaluating embodied energy, reducing landfills, and reusing existing materials this benefits ecosystems, saves resources, and reduces energy costs.
- **Profits:** The initial cost of design and evaluations may be slightly higher than conventional construction, but savings from avoiding climatic damages, recurring replacements or renovation costs far outweigh the initial design cost and adaptive reuse can result in substantial construction cost savings.
- **Place:** Reusing existing structures and planning for long life span structures contribute to a sense of place by creating a connection with human memory and history.

For many years, much of human society has seen nature as an adversary and built against it, but now we need to start seeking partnerships with nature and redefine our design practices sustainably.

In the early design stages, we need to consider the following decision matrix to encompass the above - studied factors:

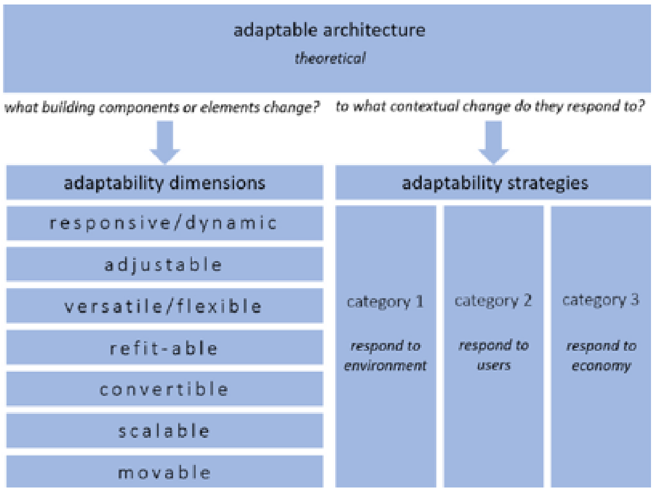

Figure 4: Decision Matrix for adaptability capacity and flexibility provisions

Transformation capacity affects reversely on environmental impact.

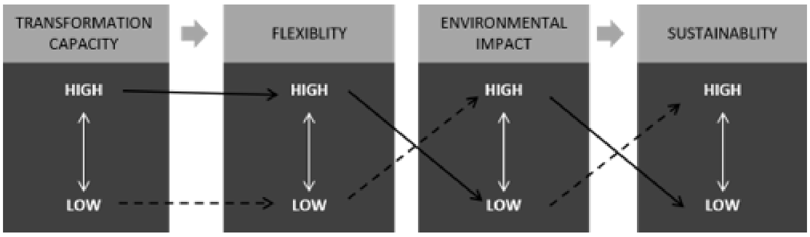

Figure 5: Relation between building conversion capacity and sustainability

To address the issue of early - stage adaptability considerations, we need to understand the building as defined by Architect Frank Duffy who coined the term, "shearing layers”

The concept defines buildings as a set of integral components that adapt or change in different timescales. Duffy notes, "Our basic argument is that there isn't any such thing as a building. A building properly conceived is several layers of longevity of built components. " [32] (Brand, 1994).

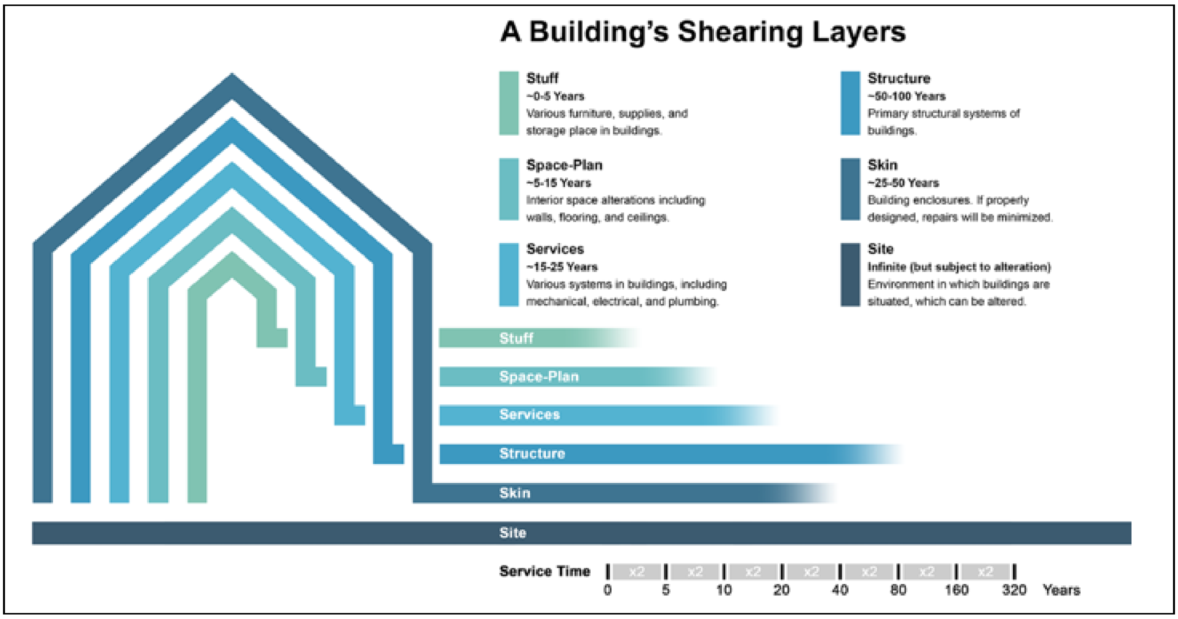

Figure 6: The "shearing layers" concept defines buildings as a set of integral components that adapt or change in different timescales. - Stewart Brand

Adapted from the World Business Council for Sustainable Development, The Building System Carbon Framework (2020).

Resiliency and adaptability start with considering a broader base of information from multiple perspectives and a core thinking principle that the building is a permanent part of the community and infrastructure.

Indeed, Lifschutz [32] wrote “The key to appropriate building design is an understanding of time, a predisposition towards buildings in continuous flux rather than static lumps. ”

Designers need to promote and instill a “long life, loose fit” approach from early design stages.

Although the context has been identified as critical to understanding and designing an adaptable built environment, it is usually considered sporadically, and the resulting research is often focused on one or two aspects of sustainability instead of taking an integrated approach [34]. Studying the context and its relationship to historical building strategies might highlight which strategies are needed in the future to address the global challenges. Wang et al. [35] argue that identifying future steps and developing a vision is critical to transition towards a sustainable built environment. Accordingly, the inclusion of adaptability concerns is crucial for to attain a sustainable built environment. In this way, adaptability should be included in the building sustainability assessment methods, enabling it to reward its potential to expand the building’s life cycle, reduce its environmental potential and promote the well - being of its inhabitants and community.

To summarize the identified indicators: “Adaptability Capacity” and “Flexibility Provisions” can be the main early - stage Design parameters to be added to design process.

Adaptability capacity measuring the space that is available to be changed according to the inhabitants’ requirements. To do so, it quantifies the Global Adaptable Space (GAS) which equals to the percentage of built area available to be transformed. Then, the adaptable area is given by the difference between the net internal area and the internal fixed area (the area that cannot be changed).

So while programming this consideration needs to be accounted for.
GAS = (NIA – IFA) / GEA

Where NIA is the net internal area (m^2), IFA is the internal fixed area (m^2) and, GEA is the gross external area (m^2). The evaluation results can be achieved with one of the approaches already described, descriptive or indicative.

The flexibility provisions can be considered on functional, component and assembly levels.

The project aspects that most affect the buildings’ flexibility are building implementation, form, structure and size, circulation and technical systems positions, and usable area size.

The level of separation between buildings’ components and materials and their function also influences the level of building transformation capacity. Nevertheless, a building should not be too flexible, as it could also hamper its benefits.

5. Conclusions

If adaptability and resilience are defined at Early Design Stages / Primary Programming Stages it can lower the project costs and improve building performance. The following 2 factors can be considered crucial:

“Adaptability capacity” is a quantitive indicator that can be calculated as a ratio measuring the space that is available to be changed according to the inhabitants’ requirements and “Flexibility provision” is a qualitative indicator and its indicative performance levels for flexibility provision can be categorised into

- Low transformation capacity
- Medium disassembly capacity
- High disassembly capacity.

As Stewart Brand eloquently put it in in his book ‘***How Buildings Learn: What Happens After They're Built’,*** our building constantly "learns" from us - the people who inhabit, utilize, and otherwise interact with our buildings.

Considering adaptability and resilience factors in the early stages of design and decision - making will address sustainability concerns holistically impacting the outcome and avoiding the premature end - of - life stage of a building project.

Various identified adaptability and resilience indicators have a transformational capacity throughout the design and problem - solving process. The resulting framework can empower the designers and other stakeholders and prove relevant in reducing environmental degradation accelerating at an alarming rate.

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