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AGILE ARCHITECTURE: HOW DO WE DESIGN FOR TIME?

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ABSTRACT

The objective of this paper is to identify and analyze the principles, approaches, and strategies involved in the design of residential buildings that explicitly take into account changing needs over a given building's life. In the view of the researchers, this pursuit is of the utmost significance, particularly in the last few decades—which can be characterized, socially and physically, by rapid shifts. For many industry professionals, flexible design has been branded as costly, difficult to deploy, and demanding state-of-the-art gadgetry. Therefore, after more than a century of attempts to design for flexibility, the issue is arguably still marginalized to the profession at large. Through synthesizing the existing literature, it became clear that design approaches have focused primarily on physical flexibility (i.e., capacity to change the spatial structure). This overly narrow approach leaves the user and the environment out of the equation, leading to the inevitable failure of the built environment's capacity to respond to social or environmental changes.
Admittedly, the attention on low operational and embodied carbon of buildings is greatly supported by near and long-term legislation agendas, particularly in the developed world. However, the present paper is after a measure that is more independent, responsive and holistic; a measure that integrates aspects of durability, flexibility and responsibility; that introduces all layers of physical, social, environmental and economic factors in the form of continuously evolving and dynamic framework; a measure that we refer to as Agile. Yet, a standard theoretical framework for setting such Agile concepts is not yet established. The proposed Agility framework consists of two parts, 1) Design Toolkit and 2) Mechanisms, Plans, and Procedures to inform Policy. The design toolkit is a three-step process, namely, 1) identify strategy clusters, 2) analyze user needs and strategies' objectives, and 3) evaluate the 'value' of the proposed strategies. The goal is to advocate a scientific approach to channel human creativity into its most productive form, eventually improving our judgement by subjecting our theories to repeated testing.

KEYWORDS

Agility; sustainability; flexibility; systems; holism; design.

1. BACKGROUND

Through our pursuit into understanding the notions of flexibility, particularly in residential projects, the most common perception has brought with it an expensive and negative connotation. For many industry professionals, flexible design has been branded as costly, difficult to deploy, and demanding state-of-the-art gadgetry. Such views have been driven, in part, by technical attempts at future-proofing buildings through the application of specific parameters such as movable partitions or over-engineering; while other buildings, which have stood the test of time have been coined accidental flexibility or simply *good* design (see Imam and Sinclair 2021). The latter argument is that flexibility is not distinctly a result of technical detailing or special componentry which allows multiple configurations to take place. Meaningful flexibility can be applied through an understanding of the fundamentals (i.e., getting the basics right). Understanding the subtle spatial and physical differences between various uses; grappling with the social, economic, political, legal, and environmental forces at play by designing architecture within a holistic context, making it conscious of time and change. Thus, the present paper synthesizes a conceptual framework for heightened Agility and sustainability, thereby realizing more responsible architecture for the 21st Century. Advancing from the established foundation of Gordon's 3L principle (Imam and Sinclair 2020), Open Building (OB) practices (Habraken, 1972; Nascimento, 2012; Imam and Sinclair 2018, 2020) and drawing upon Sinclair's recent Holistic Framework for Design + Planning (Sinclair, 2009; Imam and Sinclair 2020), the integrative model introduces continuously evolving and dynamic solutions that provide buildings with the capacity to shift and morph as circumstances warrant—in essence migrating away from the static architectural practices and staid architectural outcomes that have defined modern architecture.

In this sense, successful Agility may not always need to come from the capacity of the building itself but from the user or owner's capacity to adapt and/or any other numerous variable (e.g., social, environmental, economic, legal, political, technological) which supports the dynamic interplay between building and context. On the notion of expanding, as an industry, we have a proven set of techniques for designing homes, and we know a few best practices for building physical flexibility. However, when it comes to innovation and designing for change, we are arguably still shooting in the dark. We are relying on vision or chasing the 'good designers' who can make magic happen. The present paper attempts to put designing for change on a rigorous footing. In this new reality we live in, where work and living patterns are rapidly changing, we are at the dawn of a revolutionized architecture. It is our challenge to do our part to help create a functioning society that supports people without threatening life on Earth, including our own.

2. AGILE DESIGN FRAMEWORK

The Agile design framework consists of two parts, 1) Design Toolkit, and 2) Mechanisms, Plans, and Procedures to inform Policy. The present paper outlines the Design Toolkit. The design toolkit is a three-step process illustrating the evaluation method, as shown in Figure 1. The first step of the analysis framework is to group the design strategies into clusters by their characteristics. The design strategies were grouped by their holistic means of achieving flexibility, durability, and sustainability; and each cluster includes a set of design approaches identified through three sequential stages: literature meta-analysis (see Imam and Sinclair, 2018, 2020, 2021), survey of experts (see Imam and Sinclair, 2022), and case studies ((see Imam and Sinclair, 2022)). Analysis of each cluster provides information about the effectiveness, feasibility, and value of strategies that meet the present paper objectives (highlighted in chapter one). The two subsequent steps in the Toolkit reflect the expected decision-making process for selecting a design strategy for a particular project. First, a building user's needs are examined and classified, and design alternatives are considered that would fulfill the user's needs. The Agility provided by each design strategy is matched to the user's needs, and strategies that do not meet the user's

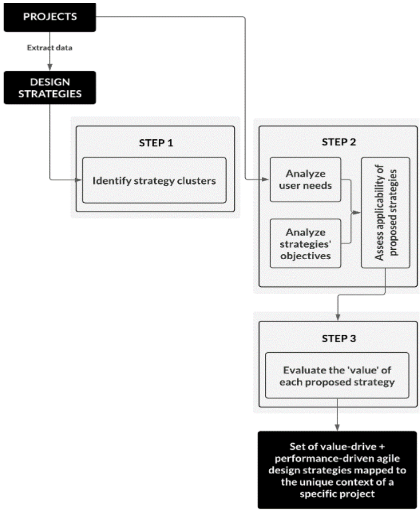

Figure 1. Model of Three-Step Data Analysis. Source: (Imam and Sinclair 2022)

needs are eliminated. Second, the limitations of the most favourable alternatives are examined to determine whether the strategy is technically feasible, and those that are not feasible are eliminated. A given strategy might be eliminated if, for example, it applies only to low-rise buildings and the user's building is a high-rise (e.g., modular panel cladding systems may not be durable enough to withstand wind loads above a certain height). Finally, the costs and benefits of favourable alternatives are examined to determine the value of the Agility gained from each strategy. Before detailing the framework steps, the qualitative units of analysis, design strategies and design approaches must be defined.

- Design Approaches: A design approach is a goal or a set of goals to enable a facility to accommodate future changes. Design approaches are more general than design strategies and do not describe the specific action by which flexibility will be increased. Design approaches often are not generalized across systems or subsystems. For example, an approach may be related to performance flexibility (e.g., to reduce the impacts of interactions between systems.) This approach is applicable to most subsystems within the building and specifies neither the particular action taken to reduce interactions nor the extent to which the interactions should be reduced.
- Design Strategies: A design strategy is an explicit action taken to improve the flexibility, durability, or sustainability (as defined in Imam and Sinclair 2021) of a building or a building's system. An example of a design strategy that increases the capacity of a building system to accommodate change is the use of modular wiring systems; their modularity allows the electrical subsystem to be easily rearranged and rewired through simplified connections. Since the design strategy is the primary unit of analysis, the independence from individual buildings and applicability of the design strategies to a range of projects is crucial.

2.1. Step 1: Identification of agile design clusters

The first step in the Toolkit groups the design strategies into "clusters" that display common characteristics (Agile Principles and Design Approaches). Clusters are identified among design strategies by agile principles (means to achieve Agility), design approaches, and change enabled (visualized in the Agile design framework Interactive). By examining groups of design strategies with one or more similar characteristics, holistic trends in the data can be identified, and conclusions can be drawn about strategies that possess such characteristics, all of which can be explored on a project-by-project basis by the design team. The results of this analysis provide evaluation data about the design approaches and clusters which, for the purposes of this paper, were grouped by the means by which they achieve Agility (see the Agile design framework Interactive).

2.2. Step 2: assess the effectiveness of Agile strategies

Measuring the effectiveness of a design strategy could be judged differently depending on the context of a specific project and the perspective of a given individual. Therefore, the proposed framework suggests implementing a system to categorize the expected and accommodated changes and comparing the Agility achieved to the needs of building occupants.

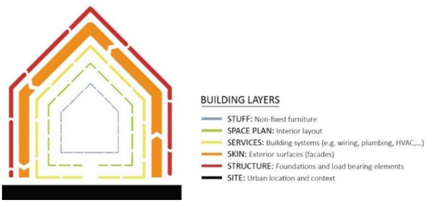

Figure 2. Stewart Brand's building layers of change and longevity. Source: (Brand, 1994)

- Interactions within and among systems: *The relationship is nonlinear*

  A key element in the proposed framework is the definition and analysis of a building as layers of systems and subsystems, which interact with one another. it is important to reiterate Stewart Brand's model (coined in 1994 and discussed in Imam and Sinclair 2021). Brand's model indicates six layers of building systems (Figure 2), each of which changes at a different rate. The present paper suggests analyzing buildings as a set of functional systems, which may or may not be physically distinct. For example, a window is a component within the exterior enclosure and the interior finish systems. The general systems of a building are divided into four general categories, namely, structure, enclosure, services, and interior finish. Each category of systems can be further divided into subsystems (Slaughter, 2001). The systems within a building can interact through various mechanisms. The nature of those interactions (and the systems themselves) influences the building's flexibility, durability, and sustainability to respond to different types of changes.

Slaughter (2001) concluded group system interactions into three general categories: physical interaction, functional interaction, and spatial interaction. Physical interactions among building systems can be through a connection, intersection, or adjacency. A roof element, for instance, can be mechanically connected to the structure, inserted through the structural elements, or simply rest upon the structure. Systems can interact functionally in ways that enhance, complement, or disintegrate current functions. For example, an exterior wall can provide additional shear capacity to a structural framing system; operable windows can complement a ventilation system, but if poorly incorporated, can sacrifice the performance of heating or cooling systems. Finally, spatial interactions occur when systems operate independently within a particular spatial region or space. For instance, lighting within a room spatially interacts in various ways with different interior surface finishes. While such systems are not physically or functionally interrelating, their spatial interaction may be crucial for the user's perception of the living space or a building.

It is important to recognize the impacts resulting from interactions between systems when evaluating the construction, operations, and maintenance of a facility, since the impacts may create a series of secondary effects in construction complexity and cost estimates. Each system in a building can be considered an independent entity in evaluation, as long as the impacts resulting from interactions of that system with other subsystems can be clearly identified and analyzed. One specific impact is the risk of progressive failure, a phenomenon that occurs when the failure of a given subsystem directly results in the failure of another. For example, using site-fixed panel partitions provides simple behind-the-wall access to wiring systems. Suppose the wiring system has characteristics that enhance its flexibility (e.g., modular wiring systems), but the site-fixed panel partitions fail to provide adequate access. In that case, the wiring system also fails to achieve its flexibility. Thus, Agility only occurs when all facets of the framework integrate.

- Change types reimagined: *Allowing designs to co-evolve with their environment*
  A building system can be expected to experience different types of changes throughout its lifetime (Table 1), changes in function, changes in capacity, and changes in flow, each of which can be further partitioned into more specific changes. The present paper expands on Maury's (1999) types of change to capture what the researchers view as necessities of the 21st century. While these change types do not describe in detail the specific changes a building undergoes, most specific changes can be classified into one of these general types.

Changes in Spatial or Function	Relates to the set of activities of components that work together to achieve a specific objective
Upgrade	The upgrade of existing facilities to meet the requirements of the building's current usage class. (e.g., improved and/or repair the HVAC system)
New Functions	The incorporation of new functions within existing facilities to meet the building's current usage class requirements. (e.g., add air conditioning to the current ventilation system)
Modifications	The modification of an existing facility to meet the requirements of and accommodate a new usage class. (e.g., add bathrooms, etc., to change an office building into apartments)
Changes in Capacity	Relates to the ability of a facility to meet certain performance requirements
Loads/Conditions	The ability of a facility to meet certain performance criteria in loads and conditions for particular usage class. (e.g., increase the number of outlet terminals in the electrical subsystem)
Volume	The incorporation of changes in overall building volume, or in system volume within a facility, to meet the requirements of the usage class. (e.g., phased development, or the addition of floors, column over capacity)
Performance-driven	Emphasizes on integrated and comprehensive integration of quantifiable measure throughout the design phases (e.g., optimize TEUI, GHGI in current and future climate conditions), as well as construction (e.g., measuring airtightness).
Changes in Flow	Relates to the interactions between a facility and the surrounding environment and its usage population
Environment	The incorporation of changes in the surrounding or internal environment within a building or facility. (e.g., enhance the ventilation system through operable windows)
People/Things	The incorporation of changes in the passage, movement, or organization of people and objects within or around a building's space. (e.g., create new stairway, or rearrange partitions)

Table 1. Definitions of building and system change types (Maury, 1999, modified by authors to reflect the represent researchers' interpretations of change types necessary in the 21st century)

- Expecting user needs: *Display emergent properties*

  User needs can be defined in a matrix form as the intersections of building subsystems and the change types. As illustrated in Table 2, the horizontal axis of this matrix delineates the building systems and subsystems, and the vertical axis lists the eight general change types. Indeed, the needs that a building user has will change over time. Some changes occur more frequently (e.g., rearrangement of partition layouts), while other changes may not occur until several years after the construction is completed (e.g., adding a new floor on top of the existing structure). The evaluation in the present paper recognizes changes that occur at all stages in the life of the building, including initial construction, operations and maintenance, repairs, renovations, and adaptive reuse. Therefore, the timeframe of each change and strategy should be a part of any framework analysis. The proposed framework classifies user needs according to three timeframe categories: Short-term (1-5 years), medium-term (5-15 years), and long-term (15-30 years). Short-term needs are common, clearly defined, and likely to be forecasted at the time of initial construction. Long-term needs are often large changes (e.g., a change in usage class) and can be more uncertain and difficult to forecast accurately early in the construction process. Medium-term needs have characteristics that fall between the short and long-term needs and often track to predicted technological advancements (e.g., development of wireless technology for the security system).

  The level of Agility achieved by a design strategy is assumed to be constant with time (i.e., strategies have the capacity to accommodate change at an indefinite time change – in the short, medium, or long-term). Because of the interactions between systems, some strategies may require changes to the design and/or construction of another system or subsystems. For example, a building's ventilation system could use the plenum beneath a raised access floor to distribute air, rather than use conventional steel ducts, allowing ventilation patterns to change by simply adding or moving floor panels containing vents. While the strategy provides flexibility to the heating, ventilation, and air conditioning subsystems (within the services system), implementing the design strategy requires changes to the finish system. To capture these factors in the analysis, the design team should use the matrix highlighted in Table 2 multiple times (i.e., repeat matrix table per building system to separate the subsystems undergoing a design change from the subsystems receiving added flexibility). It is important to note that while this matrix method may indicate agile design strategies that may not be as successful as others in achieving the specific user goals, it should provide an indication of all compared strategies that might fulfill the needs. That is, the process will eliminate those strategies that will likely not fulfill the user's needs, leaving a shortlist of effective strategies that could be considered for use once their constraints are identified—obviously, the more specific the ask or user need, the more accurate the matching.
- The Design Toolkit in practice

  Each need for Agility that a building owner or occupant has can be classified as the intersection of the appropriate subsystem and change type. Table 2 provides an example of the User needs Matrix being used to classify the needs of a particular user/owner. Comparison of the intersections provides an indicator of the effectiveness of the strategy with respect to the user's needs. It is important to recognize the feasibility of a strategy's use. Matching the user needs matrix with the Design Toolkit hierarchy, a building user's needs might theoretically be fulfilled by a strategy that is inapplicable to the particular building type or construction method. For example, the exterior wall knockout panel strategy requires extra reinforcing steel to be provided in load-bearing concrete walls in such a way that a panel can be sawed out and removed without requiring structural rehabilitation in the wall. This strategy does not work in glass curtain walls or conventional masonry structures. Strategy feasibility may also be influenced by interactions between and among building systems. For example, using modular wiring systems may be considered an effective means to accommodate changes to the electrical system, but if the wiring is routed through conduits behind conventional drywall partitions, the accessibility constrains the flexibility. If the modular wiring system is distributed to outlets beneath a raised access floor, the technical characteristics of the floor (i.e., reachable) improve the ease of construction necessary to accommodate potential change.

		Structure		Enclosure			Services										Finish			
		Sub-structure	Super-structure	Walls	Openings	Roof	Heating	Ventilation	Air Conditioning	Lighting	Electrical	Telecom	Security	Plumbing	Fire Protection	Circulation	Floors	Walls	Openings	Ceiling
Function	Upgrade																2	3	3	3
	New Function																			
	Modifi-cation																			
Capacity	Loads & Conditions										4	4	4							
	Volume																			
	Perfor mance -driven					1														
Flow	Environm -ental																			
	People & Things						5	5	5	5	5	5		5	5	5		6	6	

Table 2. User needs matrix in practice, demonstrating the means to classify the needs of a particular user, sampling a list of changes expected in a residential building. Numbers correspond to the following change items: 1) Roof will need to be renovated to improve thermal performance (R-value), 2) Carpeting will wear out and will possibly require a frequent upgrade, 3) Interior designs will alter for aesthetics preferences, 4) accommodate more outlet terminals will be required for electricity, telephones, and computers (accommodating possible apartment split), 5) many services will have to be rearranged to accommodate layout changes, 6) Space is expected to be re-arranged

	COST OR BENEFIT	MEASUREMENT	DESCRIPTION OF MEASUREMENT
Design/Initial Construction	Design difficulty	simple difficult	- design is not overly complex or does not require special skills beyond that of ordinary professional designer. - design is complex enough to require special skills beyond that of ordinary professional designer.
	Ease of construction	- easy - difficult	- construction activities require no extraordinary training. - construction activities require extraordinary training.
	Construction duration	no impact shortened lengthened	- construction duration is approximately the same as with conventional designs. - construction duration is expected to be shorter than conventional designs. - construction duration is expected to be longer than conventional designs.
	Safety concerns	No Yes	- design strategy present no significant safety concerns. - design strategy present significant safety concerns.
	Procurement concerns	no yes	- design strategy no unconventional materials. - design strategy unconventional materials.
	Financial cost	percent change variable	- percent change in cost of building from conventional construction. - complexity of system designs prohibits accurate cost estimation, and system cost varies positively and negatively depending on specific design attributes
Operations and Maintenance	Financial cost	increased not significant decreased not applicable	- O&M activities are more expensive, difficult and/or time consuming. - O&M activities are no more expensive, difficult and/or time consuming than for conventional designs. - O&M activities are less expensive, difficult and/or time consuming design. - requires no maintenance
	Accessibility for operations and maintenance	no change improved access worsened access not applicable	- accessibility for repairs is neither better nor worse than in conventional designs. - accessibility for repairs is much easier than in conventional designs. - accessibility for repairs is much more difficult than in conventional designs. - there are no O&M costs associated with either design strategy or the conventional alternative.
	Irrevocability of commitment	minimum significant failure	- in the event of failure, a new design can be used at minimum cost. - in the event of failure, a new design can be used but at a major cost. - in the event of failure, the design cannot be replaced affordably.
Change Implementation	Financial cost	change in cost variable alternative is cost prohibited	- change in cost of implementing a change in the design strategy as compared to conventional construction techniques. - complexity of system designs prohibits accurate cost estimation, and system cost varies positively and negatively depending on specific design attributes. - design strategy allowing for change is not feasible, either technically or economically, when conventional designs are used
	Downtime	no impact shortened lengthened	- during a change, the interruption of occupied space is the same as for conventional designs. - the interruption of occupied space is shorter than conventional design practices. - the interruption of occupied space is longer than conventional design practices.
	Accessibility for renovation	no change improved access worsened access	- accessibility for change construction is neither better nor worse than in conventional designs. - accessibility for change construction is easier than in conventional designs. - accessibility for change construction is more difficult than in conventional designs

Table 3. Descriptions of the measurements of the costs and benefits of Agility

2.3. Step 3: assess the value of Agility

Benefits of agile design strategies can be in many forms: reduced financial costs, shortened construction schedule and/or downtime, climate resilience, thermal comfort, avoided premature functional or physical obsolescence, as well as less-quantifiable aspects like enhanced aesthetics, ease of construction, safety, and risk of failure. The decisiveness of the commitment to the system layers designs is also an important consideration in the valuation of a strategy since a system design that is easily or cheaply replaced with another reduces the consequences of system failure. Likewise, the 'cost' of Agility (meaning a capital commitment, rather than a negative financial value) can take the same forms. These costs and benefits are intended to be realized by different parties in the construction process, which likely occur at different milestones during the life of the building.

The proposed framework identifies three timeframe categories: initial design and construction, operations and maintenance, and change implementation. These timeframes help describe the distinct types of construction activities that occur in the life of a building. The design strategy is first implemented either during initial construction or renovation when steps are taken to accommodate changes in the future. A change (or a series of changes) is implemented at a later stage. In the time between initial construction/renovation and the first change (and between subsequent changes), the design strategy may directly impact the operations and maintenance activities that occur. The costs and benefits evaluated represent the significant impacts that the design strategy has on the building, user, and owner during these three timeframes. Table 3 lists the costs and benefits evaluated or measured for each design strategy in this analysis, along with each associated measurement. The only clearly quantifiable measure used is an order of magnitude estimate of the cost, as compared to conventional techniques. Since cost estimates performed by contractors may vary widely depending on their capabilities, geographic location, and current construction market, estimates to determine the specific cost should be evaluated on a project-by-project basis.

3. CONCLUSIONS

3.1. How do we design for time?

Significant flexibility can be achieved as a result of reducing interactions between systems, especially reducing the physical and spatial interactions between the finish and service systems. This is a common means of creating flexibility in one system by altering the design of another. These interactions also occasionally impose restrictions on the use of certain design strategies. Most frequently, it is the structural system that imposes these restrictions on a strategy's use, regardless of the system to which the design strategy is applied. The cost of implementing a design strategy during initial construction typically increases the overall building cost, though the literature suggests a relatively controlled increase of less than 2-3 percent. Obviously, some strategies will have higher cost increases, typically resulting from the use of unconventional building materials or specialty products that are expensive or difficult to procure.

The selection of the most suitable strategy depends on several factors, such as the structural typology and technologies of a building, its historical and functional importance, and the socio-economic issues connected with the presence of serious damages and obsolescence. Typically, the ratio between the costs and the performances achieved should be determinant for the definition of the design or retrofit programs. In other words, synergetic operations should improve the overall characteristics of the buildings, at the same time reducing the ancillary construction expenses. In the view of the researchers, the actual problem arises when the emphasis shifts to the technical and constructional aspects of a project and away from the more socially grounded implications of Agility. When techniques become an obsession, then technology becomes an end instead of a mean to reach an end. The solution is instead to use technology and innovation to create a framework for agile housing, abandoning the idea of strict determinism and strategically allowing a degree of "controlled freedom."

This brings us back to the question posed in title: How do we design for time? From the authors' perspective, technical feasibility alone does not accomplish an agile solution. The concepts and means of Agility discussed in this paper bring an emphasis on process and enabling the building to 'learn' and the users to 'teach' or shape the space themselves. Agility aims for the design to become an ongoing social process between the designer, user, and community within. The designer is responsible for enabling durability, flexibility, and sustainability to take place, as opposed to attempting to control experiences and anticipate the future. In reality, architecture is placed inside a rather unpredictable context where it is forced to respond to and act on exogenous demands or suffer premature obsolescence. It is here where *good* design takes place through the conscious understanding and negotiations of these demands towards synthesized solutions which recognizes the dynamic nature of the context in which the building exists and will continually evolve with time. The present paper views Agility as a design principle that brings time and change to the forefront of thought but requires a reconceptualization of time through shifting mindsets and unifying of values. That said, placing architecture in context may suggest to under design rather than over design, to leave space unfinished as a mechanism for engagement. The unprecedented consequences of COVID-19 and climate change mark what the authors see as the beginning of the end of traditional architecture and urban design as we know it. Incongruously, almost every traditional AEC organization, while trying to figure out its place in this changing world, is stubbornly trying to build a bulwark to protect old models that can't possibly survive the sea of change underway. Thus, from the author's perspective, if change is the new problem; Agility is the new solution.

3.2. Becoming the status quo

Every framework eventually faces an overriding challenge in developing successful products (architecture): deciding when to pivot and when to persevere. The arguments and recommendations discussed in the present paper are prelude to a seemingly simple question: are we making sufficient progress to believe that our original strategic hypothesis is correct, or do we need to make a major change? Because of the scientific methodology that underlies the Agility framework, there might be a misconception that it offers a rigid formula for making design decisions. This is not true. There is no way, nor does the proposed framework intends to, remove the human element—intuition, vision, judgement—from the practice of architecture or designing for the future.

Fast-forward several years to when Agility concepts are well-practiced, this last transition can be especially difficult for innovators and architects to accept: their transformation from radical researchers and practitioners to the embodiment of the status quo. Most researchers and practitioners are likely to get caught between applying comfortable means and methods (those ideas that became part of the status quo) and constantly entertaining suggestions for ways they could be improved. Above all, how do we know that “your way” of designing for the future will work? How can we mitigate costs and risks? How can we educate the next generation of architects about Agility concepts? It is these questions that require the use of theory to answer. The goal is to advocate a scientific approach to channel human creativity into its most productive form, eventually improving our judgement by subjecting our theories to repeated testing.

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