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Design Thinking for Innovation in Sustainable Built Environments and the Integration of an Inclusive Foresight and Design Thinking Framework

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ABSTRACT

The search for new methods and tools to successfully address sustainability challenges is gaining momentum, due to the growing awareness of sustainability issues. Over the past two decades, design thinking (DT) has become a phenomenon in a wide range of contexts, and has recently drawn research attention as an innovative approach for handling complex socio-ecological problems. This review paper analyzes DT processes covered in sustainable built environment (SBE) articles that focus specifically on DT and innovation, with a view to suggesting/developing an affective new model for sustainability research. The research design was developed following Denyer and Tranfield's method. The author reviewed documents using the evidence from all open access English language articles related to this issue between 2000 and 2022 identified using a Scopus database search in order to clearly identify and analyze the challenges and opportunities for innovation growth in SBE using a DT and innovation framework, 50 articles were selected based on the PRISMA statement and plotted on a modified Ansoff Matrix. This systematic literature review indicates that research regarding DT for innovation in SBE is challenged by the matter of how to identify new contexts and new solutions for future-oriented sustainability. It is also proposed that a wider range of stakeholders are required to help optimize the solutions being generated. The results reveal research gaps in integrating foresight and DT into sustainability research. A model of inclusive foresight design thinking (FDT) is proposed to guide future research to support the practical application and enhance the viability of DT in sustainability.

1. INTRODUCTION

Sustainability is now a major driver of innovation, and innovation itself is now recognized as a vital contributive factor to success, competitive advantage, and survival [1, 2]. As noted by Nidumolu et al. [1]: "… sustainability is a mother lode of organizational and technological innovations that yield both bottom-line and top-line returns." Many widely recognized global environmental problems are either directly and/or indirectly caused by activities associated with creation, operation, or disposal within the built environment [3]. The construction industry plays an important role in the growth and development of the economy; however, it is also the industry that dominates the worldwide consumption of raw materials [4]. The degradation of natural resources, the climate crisis, and energy shortages are exceedingly complex phenomena. These challenges require innovative solutions to drive new socio-technical and socio-ecological systems [5]. To help successfully address these issues, new approaches of innovation for sustainability are required to achieve practical and sustainable solutions to help the world reach its the sustainability development goals (SDGs) [6, 7].

Design thinking (DT) is an approach used to generate innovative and creative solutions to complex and uncertain challenges involving many stakeholders [8]. Recently, DT has attracted research attention as an emerging approach that can be adopted to cope with complex socio-ecological problems [9]. DT is recognized to be both a significant tool and a promising new approach for simplifying problems in areas ranging from business management [10, 11] to the provision of public services, with a focus on social issues [12] and sustainability [8, 9]. While the design approaches for sustainability are well established, there has been limited integration of DT within research into creating the sustainable built environment (SBE). In addition, The connection between sustainability and foresight is widely discussed [13]. Thinking about plausible futures that could benefit all of us in terms of economic, environmental, and social types of constraints has become the norm in sustainability [13]. However, the study of SBE is still mostly ignorant of the possibility that foresight could be a significant tool in addressing sustainability and one of the finest ways to prepare sustainable solutions.

Aiming to examine and help fill the gap regarding DT and foresight's potential contribution to SBE, this review addresses the following research questions: what contribution does/can DT make to SBE? And what is required to develop a new DT model for the study of SBE? The research design was developed following Denyer and Tranfield's method. The paper aims to provide a comprehensive and systematic review of DT literature in relation to SBE using the evidence from all open access English language articles between 2000 and 2022 identified using a Scopus database search. In total, 50 papers were assessed in order to assess innovation in SBE and to illustrate the innovation factors driving the issues being addressed. The results indicate that while DT can have a positive impact on SBE, the opportunity exists to integrate foresight into DT practice for sustainability in order to show how DT can deliver immediate solutions at the same time as proactively addressing future challenges to environmental sustainability. It is proposed in this review that DT processes can be improved through creating a new foresight and DT framework to enable stakeholders to proactively take such factors into account to enable more effective and beneficial sustainable development and planning in the built environment.

This work provides a preliminary critical framework for developing a new model that integrates DT and foresight approaches, as well as identifying opportunities and future challenges in the field of SBE. The author first discusses the background of DT and sustainability, as well as providing a critical literature review of SBE. Then, materials and methods to develop this area further are provided for discussion. In particular, the author develops an analysis framework according to a modified Ansoff Matrix with this aim in mind. Subsequently, the research results are provided, and the author proposes a new approach for using DT for innovation in sustainability, utilizing a model of foresight design thinking (FDT). The author then draws conclusions about the applications and considerations of the FDT model, demonstrating its practical implications and making future research suggestions.

1.1 Design thinking and sustainability

Design can be defined as the conscious act of changing an existing situation into a more preferred one [14] and DT represents a designerly way of thinking about a range of design problems. Several definitions of DT have been offered, including those that focus on creative and innovative problem-solving [10], abductive reasoning [10], and a method used in multidisciplinary settings [10, 11]. Scholars have defined DT from various perspectives. In a business and management context, DT is described as an iterative user-centered approach and a mechanism that adds value, encourages creativity, unlocks innovation, and generates economic benefits [11]. DT is recognized to be an essential tool and an emerging approach for problem solving in areas ranging from business management [10, 11] to public services, and social innovation [12] to sustainability issues [8, 9]. Design is a discipline that addresses complex challenges and can be extended to critical areas of the sustainability field. Design has the potential to influence consumption and product lifecycles, and DT can be a key driver in the necessary transition to a more sustainable society [15].

1.2 The sustainable built environment

The acceleration of global crises has greatly increased the demand for sustainable buildings and construction. The built environment is a major energy consumer, and the building construction sector has an impact that is both environmentally and economically significant [16]. According to the global status report for building and construction [17], in 2018, 36% of final energy use and 39% of energy- and process-related carbon dioxide (CO_2) emissions were derived from it. In addition, 11% of these emissions resulted from the manufacturing of building materials and products such as steel, cement, and glass. Moreover, the building construction sector is a significant consumer of natural resources and creates considerable environmental impacts [18].

As a result of climate change, urbanization, the expansion of globalization, and industrialization, more attention is now being paid to the built environment, and especially to the construction industry [19]. The SBE approach has expanded its role to intervene in the lifecycle of environmental resources used in this industry [19]. This intervention in the process of producing products and services, as well as in amending consumption patterns, aims to encourage sustainable development [19] and contribute towards a circular economy (CE). The transition towards a SBE reflects a fundamental shift in the way that resources and energy are used in the construction industry [20]. It also represents a change in how issues should be addressed. Examples observed in the literature reviewed include the transition from high levels of waste to high levels of reuse and recycling, from non-renewables to renewables, and from products based on the lowest first cost to those based on lifecycle costs [20].

In addition, SBE can refer to the approach of maximizing resource saving over the resources' lifecycle, reducing energy consumption, reducing pollution, and protecting the environment [21]. It can also be reimagined to include better assessment of how ideas are likely to be received by stakeholders, and indicates how designers, developers and specifiers can better make informed choices to avoid the likelihood of costly mistakes. As noted by Weber [22]: "… inhabitant-centricity and citizen engagement are deciding success factors for any … transformation, it becomes vital to put inhabitants first." For reasons such as this, it is proposed that an inclusive foresight and design thinking framework should be developed and applied.

2. MATERIALS AND METHODS

This paper provides a systematic review of the applications of integrating DT into the SBE so as to describe the practical applications of such an integration, and to suggest a new model of FDT. To achieve these goals, the research design was developed following Denyer and Tranfield's method [23]. As shown in Figure 1, this method is comprised of five steps: (1) question formation; (2) location of studies; (3) study selection and evaluation; (4) analysis and synthesis; and (5) reporting and interpreting the results.

The methodology for the systematic literature review uses an approach based on the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement [24]. The review itself is comprised of three review phases, namely: (1) the identification of candidate articles; (2) the screening of full-text English language articles for eligibility and keywords, including "design thinking", "sustainability", and "built environment"; and (3) defining the inclusion criteria for the review and qualitatively synthesizing the final sample of eligible articles.

Literature was gathered between 10 September 2022 and 25 September 2022. It consisted of five phases: (1) database search; (2) eligibility assessment; (3) English article scanning; (4) keyword scanning; (5) design thinking, sustainability, and built environment identification. For database search, the author identified the relevant articles through the Scopus database using article titles, abstracts, and keywords that included "design thinking", "sustainability", and "built environment." There were 947 document results; of these, 364 were open access articles. In the second stage of eligibility assessment, only full-text articles accepted following the eligibility assessment were included. This resulted in a total of 334 articles. For English article scanning stage, 5 articles were removed. Then, 329 full-text English language articles were subjected to the fourth stage, “keyword scanning”. There were 301 articles that provided keywords. The fifth stage comprised the identification of main ideas related to design thinking, sustainability, and built environment. In total, 50 articles were found to be relevant to design thinking, sustainability, and built environment and selected for further analysis.

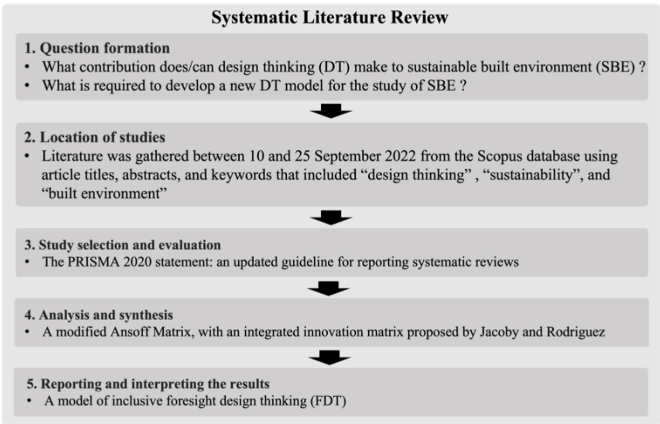

Figure 1. Research design schema

2.1 Data description

The 50 papers assessed are comprised of 41 journal papers and 9 conference papers. Table 1 lists the articles on research into DT integration published and the areas of built-environment-related research they covered.

Table 1. Articles on research into DT integration published in different areas of built environment research

Area	Number	Citations
- Affordable and clean energy	4	[25-28]
- Inclusive and healthy neighborhoods and buildings	2	[29, 30]
- Methods, strategies, tools, and practices in delivering sustainable solutions	24	[5, 8, 17, 31-51]
- Net zero carbon and the circular economy (CE)	11	[52-62]
- Urban planning and processes for sustainable development	9	[63-71]

2.2 Review framework

To clearly identify and analyze the challenges and opportunities for innovation growth in SBE, 50 articles were selected and plotted using a DT and innovation framework. The term innovation is widely used and discussed in many contexts across academic disciplines. Innovation refers to creativity and novel solutions; however, the overuse of the word often detracts from its value [72]. Innovation can be defined as the ability to outperform and deliver new value [73]. The link between innovation and design arises from the fact that creativity is a significant ingredient for innovation [16], and innovation requires acts of design and DT to approach and resolve challenges successfully [72].

Innovation is often used synonymously with advanced technology, as well as creativity and novelty solutions [72]. However, the outcomes of scientific breakthroughs are just one type of innovation. Innovation also encompasses new applications or combinations of existing scientific or technological knowledge that meets users' needs [74]. This review proposes the use of a modified Ansoff Matrix, with an integrated innovation matrix proposed by Jacoby and Rodriguez [75], as a DT and innovation framework to bring together research findings. The modified Ansoff Matrix shown in Figure 2 depicts a 2x2 matrix with the two categories of challenges, familiar and unfamiliar, framed against two categories of solutions, known and unknown.

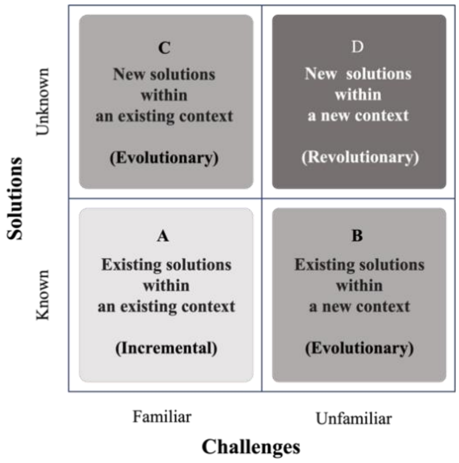

Figure 2. Modified Ansoff Matrix depicting four different types of innovation

(A) The lower left quadrant is where the challenges are familiar, and the solutions are known. This leads to better-quality outcomes and contributes to incremental innovation, which offers existing solutions within an existing context.

(B) The lower right quadrant is where the challenges are unfamiliar, and the solutions are known. This generates adaptive outcomes and contributes to evolutionary innovations that apply existing offering solutions to a new context.

(C) The top left quadrant is where challenges are familiar, and the solutions are unknown. This leads to leveraging outcomes and contributes to evolutionary innovation, which offers new solutions within existing contexts.

(D) The top right quadrant is where challenges are unfamiliar, and the solutions are unknown. This generates disruptive outcomes and contributes to revolutionary innovations that offer new offering solutions within new contexts.

Adopting such a framework helps us to identify the appropriate types of sustainable innovation growth, recognize the scope of challenges, and deploy an appropriate innovation process and innovation assessment portfolio [75]. The mapping outcomes are derived from an analysis of the method, process, or tool used as a solution in the research study, as well as the context. For incremental outcomes, an execution-focused process and a human-centric approach is required. The incremental outcomes focus on understanding, not exploration. For revolutionary outcomes, an exploration-focused process, and a human-centric and future-oriented approach are required. The foresight framework is an important tool for exploring plausible futures. For evolutionary outcomes, an ideation-focused and human-centric approach is required. Evolutionary outcomes can be further differentiated as to whether they focus on adding new value to an existing context or to a new context. These differences can be mapped out in the DT and innovation framework.

To increase the probability of achieving sustainable innovation, it is critically important to consider new contexts and new solutions, and evolutionary innovation, what has already worked successfully in the past and may be adapted and improved upon. Each project is fundamentally different, and each project's origin is unique. Yet it may contain elements of solutions successfully applied by others in different contexts, and/or the application of new approaches and technological breakthroughs. What is revolutionary to one project is incremental to another project; these categories are all relative, based on the outcome-centric structure of the innovation process [75]. To achieve future-oriented sustainability, the key driving forces rely on defining the new context and imagining new solutions. Unfamiliar challenges derive from new contexts. The important questions are as follows: Will the project's outcomes also respond to the user experience in the future? And how can we formulate new solutions that are currently unknown in order to respond to a new context?

3. CONSIDERATIONS

Innovations are often key to the success of SBE solutions. By classifying and summarizing the 50 selected papers, the status, and practical applications of DT in the field of SBE are discussed from the following four viewpoints:

3.1 Existing solutions within an existing context (Incremental)

The lower left quadrant of the modified Ansoff Matrix shown in Figure 2 is where the challenges are familiar, and the solutions provided are known. This leads to higher outcome success and contributes to incremental innovation, which offers existing solutions within existing contexts. This incremental innovation can be defined as an improvement within a given frame of solutions, or as a continuous modification of previously accepted practices [76]. The challenges in this group include the issue of household water consumption, waste sterilization systems, sustainable practices, construction, architecture and building, design and design practice, supply chains, urban issues, and policy.

The existing context and solutions encompass several issues: (1) The prediction of the range of household water consumption in Huelva, Andalusia, Spain. The article accessed uses a web-based prototype within a DT framework based on a human-centered methodology to engage households and mitigate the risks associated with development and adoption [31]; (2) The case of a sustainable waste sterilization system in the Piedmont Region, Italy, using a DT framework to develop a new method for the treatment and disposal of infectious waste [34]; (3) Sustainable practices developed from DT and social practice theories, aiming to create a toolkit to design interventions that unlock unsustainable practices [36].

The existing context and solutions related to construction are discussed in four papers: (1) a case of an adapting reused of building construction waste into new building construction materials using a DT process [37]; (2) a DT method to develop a practical guideline for construction waste minimization [38]; (3) a case study of construction equipment concerning the use of physical prototypes for the development of product-service systems (PSS) enabled by new digital technologies [32]; and (4) extending producer responsibility in offshore prefabrication construction using a conceptual framework with a DT process [50].

The existing context and solutions related to architecture and building are addressed in three papers: (1) the Fuzzy Delphi Method (FDM): based on DT and communication theory, which is used to investigate the semantic difference and cognitive gaps among participants in the design review process [39]; (2) specific design guidelines and strategies for implementing the Japanese Metabolism are proposed (these focus on buildings that are recreatable and adaptable to change) and combine DT in their practice [48]; and (3) an investigation of opportunities for DT to deliver sustainable solutions in the built environment, as well as a potential application including social innovation (human-centered) and disruptive innovation (transformational) approaches [17].

The existing context and solutions for design and design process are addressed in two papers: (1) an assessment of sustainable smarter specialization strategies, using an efficacious multi-criteria approach that leverages DT philosophies and agile methodologies [33]; and (2) the rebuild-by-design process, a process to drive innovation and deliver resiliency projects and strategies that can be implemented and leveraged to produce a catalytic impact on a broader scale regarding disasters in US coastal cities and towns [40].

Regarding supply chains, there are two papers that focus on this topic: (1) the sustainability transition in supply chains using the Double Diamond design process model to formulate a DT overview and trace potential research gaps in the selected frameworks and models regarding the sustainability transition of supply chains [46]; and (2) a process model based on the DT model for innovation related to the realization of sustainable supply chain innovation [59].

There are two papers that address urban issues: (1) a study of urban community development in Thailand that uses DT to identify its potential and facilitate an informal discussion, using prototypes with members of the local community to discuss the situation before urbanization loosened community ties [68]; and (2) a study of the professional performance of urban designers, using a comparative framework and the applied knowledge of professional practice for a better understanding of DT in urbanism [35].

Finally, there are three articles related to policy issues: (1) participatory public service design to increase citizens' satisfaction levels with public services using DT [65]; (2) the policy capacity for public transport of local government units in Philippines, using a co-design approach to support the analytical, operational, and political policy capacities of government bodies [70]; and (3) a project development framework for creating strategic plans of the equipment, vehicle, and tool management plans appropriate to the Department of Rural Roads in Thailand, which uses DT principles as the foundation for the research methodology [71].

3.2 Existing solutions within a new context (Evolution)

The lower right quadrant of the modified Ansoff Matrix shown in Figure 2 is where the challenges are unfamiliar, and the solutions provided are known. This leads to adaptive outcomes and contributes to increased evolutionary innovation, which offers existing solutions within a new context. This radical innovation can be defined as a change in the framing context, or as a new context. The challenges in this group include climate change, the energy transition, smart building, and CE. Regarding climate change, one article offers innovative climate adaptation solutions for a high-flood-risk region of the Lake District, UK, which utilize the DT process to propose a design strategy [45]. The two articles related to energy transition are: (1) case studies of zero-energy renovation/building in the Netherlands using sociotechnical design, participatory design, and inclusive design [26]; and (2) a case study of energy-flexible factories in the model region of Augsburg, Germany, using the DT method [27].

There are four papers directly related to smart buildings: (1) a study of the role of architects in creating the image of an elderly-friendly sustainable smart city using the DT method [29]; (2) a conceptualization of smart buildings that provides new service opportunities, guided by a DT approach [44]; (3) a new approach for eliciting and defining problems for sustainability-oriented innovation using the DT and systems-mapping approaches [49]; and (4) the design of smart building operations and maintenance management service systems using service design and systems DT as a guide [51].

For CE, there are six papers: (1) A CE for the data center industry using a whole systems approach, DT, and the Double Diamond methods [52]; (2) A study of the sustainable DT approach and its theoretical framework. That paper focuses on a CE in relation to sustainable DT and social innovation [55]; (3) Design-led innovation, in a CE in Singapore and in Townsville, a regional city in Australia, using DT and service DT as a strategy for innovation [56]; (4) An exploration of two regional areas in the state of Queensland (the Sunshine Coast and North Queensland) for design-led innovation in a CE using DT, service DT, and co-creation [57]; (5) CE policy design processes driven by a systemic DT for policy-planning on a circular transition in EU regions [58]; and (6) The use of DT to create a way forward in co-creating future meaningful experiences with renewable energy infrastructures [62].

3.3 New solutions within an existing context (Evolution)

The top left quadrant of the modified Ansoff Matrix shown in Figure 2 is where the challenges are familiar, and the solutions are unknown. This provides leveraging outcomes and contributes to the evolutionary innovation which offers new solutions within an existing context. This radical innovation can be defined as a change in the framing solution, and as comprising new, unique, and discontinuous solutions. The innovation in this category is associated with familiar challenges or an existing context. However, the solutions provided here are new.

The papers in this group cover the following: (1) integrated urban-energy planning that combines detailed multi-energy modelling and a user-centered collaborative development process in the early phases of an urban project for the redevelopment of the Berlin-Tegel airport [25]; (2) an interdisciplinary approach for building energy efficiency using design innovation techniques, existing energy audit methods, and data-driven and engineering modeling techniques [28]; (3) a new approach for SBE involving citizen-expert design-thinkers, using the iterative approach of the DT process [47]; (4) a smartbottle ecosystem based on the association of DT and participatory design as the basis for sustainable design at the Polytechnical Institute of Viana do Castelo, Portugal [67]; (5) the application of the Living Labs concept in the management of a coastal area of Constanta (Romania) using the DT approach [64]; and (6) a systematic integration of user's considerations in the design and testing of the sustainable product-service systems of sustainable Living Labs, using the integration of the co-creation method of urban DT [63].

3.4 New solutions within a new context (Revolution)

The top right quadrant of the modified Ansoff Matrix shown in Figure 2 represents where the challenges are unfamiliar, and the solutions to be provided are unknown. This provides disruptive outcomes and contributes to revolutionary innovation that offers new solutions within a new context. The foresight framework is an important tool for exploring the plausible future that defines a new context. Social, Technological, Economic, Environmental, and Political (STEEP) factors are used to investigate unfamiliar challenges. STEEP is a foresight-study initiative that organizations deploy when exploring future challenges [77, 78]. The new contexts found in this present review follow STEEP factors, including: the issues of an ageing population and engaging the community in smart cities (the social factor); the issue of smart homes and the age of cyber-physical systems (the technological factor); the issues related to sustainable innovation and SDGs, circular-oriented innovation (COI): urban climate change adaptation, and upcycling (the environmental factor); the issue of circular business models (the economic factor); and the issue of AI for sustainable environmental governance (the political issue).

3.4.1 Social factors

This review found two critical future challenges related to the social factor, the ageing population and the development of smart cities. In terms of the ageing population, the world is experiencing a growing elderly population. This future challenge requires the built environment to be appropriate for ageing people and designed for autonomous ageing to support the reduced physical, mental, social, and functional capacities of older people [30]. To address this challenge, the literature accessed deploys a human-centered approach to design for autonomous ageing [30]. For the issue of the smart city, the literature points out the rapid growth of the Internet of Things (IoT): ambient intelligence, crowdsourcing, and the need for the inclusive engagement of people [69]. The literature describes the use of a design-computational thinking approach to develop computational perspectives for community-based engagement and innovations in smart cities [69].

3.4.2 Technological factors

This review highlights two important issues regarding the issue of smart homes and the issues that arise in the age of cyber-physical systems (CPS). Regarding the issue of smart homes, the adoption of technological innovations embedded in a smart sustainable building is important [42]. The literature proposes a conceptual model to create and select smart home conceptions from a user-centric and sustainable perspective, using the DT approach [42]. Regarding the issue of the age of CPS, the literature discusses the topics of collaborative robots, smart cities, and autonomous vehicles. To optimize the potential of CPS to support a more sustainable future, the literature contributes to transdisciplinary skills and a combination of different mindsets, including the systems mindset, the design mindset, and the futuristic mindset, to enable creative transdisciplinary work for a human-centered and sustainable future [66].

3.4.3 Environmental factors

The environmental factor covers four issues: sustainable innovation and SDGs; COI; urban climate change adaptation; and upcycling. With regard to sustainable innovation and SDGs, the literature introduces MetaMAP, an interactive graphic tool and framework for designing well-integrated sustainability initiatives and managing synergies and trade-offs regarding the SDGs in order to achieve SDGs with more integrated approaches [6, 41]. Another work proposes Geneva impACTs, a new approach for fostering sustainable innovation, which is based on a combination of systems theory, collective intelligence, agile development, and DT [5].

The literature defines COI as a problem-centric and action-oriented iterative process that aims to create business opportunities in the transition toward a CE [79, 80]. One article presents the Circular Collaboration Canvas, a tool that integrates decision-making principles in a DT approach to stimulate the collaborative ideation of circular propositions [53]. For the issue of urban climate change adaptation, the literature argues that the co-creation process is key to dealing with environmental issues and introduces a life cycle co-creation process, developing continuous improvement cycles and DT methodologies to tackle the problem [54]. Finally, for the issue of upcycling, the literature discusses the waste management issue in Singapore and proposes an upcycling practice using a mobile app-aided DT approach to reduce the barriers to upcycling by aggregating the materials available in the market and crowdsourcing upcycling know-how [61].

3.4.4 Economic factors

Adopting innovative sustainability approaches are likely to result in significant cost savings. In recent years, awareness has grown into the application of CE as a powerful approach for moving towards sustainability. The concept of the CE has now gained traction in industry and policy as a pathway to achieving resource efficiency [40]. However, the practical transition towards a CE poses critical challenges, especially in the implementation of circular business models [60]. The literature provides Circular Sprint, a DT-based framework to guide the early development of circular business models in an online and time-efficient manner [60].

3.4.5 Political factors

The literature indicates the high value of artificial intelligence (AI) for sustainability in facilitating and fostering environmental governance [43]. To show how AI can contribute to environmental sustainability, and to identify how AI solutions can be combined with human and behavioral responses, the literature integrates: (1) multilevel views; (2) systems dynamics approaches; (3) DT; (4) psychological and sociological considerations; and (5) economic value considerations, to achieve the real value of AI for sustainability [45].

3.5 Design thinking for future-oriented sustainability

Sustainability is viewed as an ongoing process of change as opposed to a concrete condition that can be defined [81]. The possibilities and constraints of DT in sustainability are argued to contribute to sustainable practices and solutions for desired futures. DT applied as an abductive approach is particularly ideal to reveal emergent solutions to situations when neither "the problem" nor "the solution" are fully known [82]. However, this systematic literature review indicates that research regarding DT for innovation in SBE is challenged by the matter of how to identify new contexts (unknown) and new solutions (unknown) for future-oriented sustainability. The only thing we have is a " desirable future," but we are unsure of precisely "what" to build or which "working principle" to apply when creating the aspired value [83]. Exploring alternative futures is a leap into the unknown that benefits from a participatory creative process [83]. The fact that so few DT methods are used for innovation in sustainability, taken along with the fact that sustainability is now the key driver for innovation, indicates that there may be a huge opportunity available to explore DT for future-oriented sustainability.

DT serves as a mechanism that enable and promote innovation and sustainability. As a framework, DT alternates between divergent and convergent thinking-processes and offers a particular method of abductive reasoning that enables designers to think outside of the box and discover fresh, innovative ideas [84]. Imagination makes the impossible possible and can generate potential solutions where non previously existed. Forward looking DT can include looking at future projections on STEEP factors, such as demographic change, technological breakthroughs, climate change, circular economy, low-carbon economy, smart governance, etc., and provide an indication of what kinds of innovative solutions may be required to best address them. Also consider taking in a wider range of stakeholders into the DT process [85], particularly those representing 'at risk' groups, as this can increase knowledge databases beyond people's normal comfort zones and help them gain a better overall picture to develop more holistic and effective solutions. As part of this it can also look at a wider range of specialist stakeholders in order to better understand the challenges faced. A wider range of stakeholders are required to help optimize the solutions being generated.

4. A PROPOSED NEW APPROACH FOR DESIGN THINKING FOR INNOVATION IN SUSTAINABILITY

We are living in a period of intense Turbulence, Uncertainty, Novelty, and Ambiguity (TUNA) [86]; a world where contexts change rapidly and unpredictably. In this period of great uncertainty, we need new approaches and revised mindsets to better address the challenges we face [86].

We also need to listen to a wider range of stakeholders that can better build on each other's ideas to gain better understanding of the challenges faced. It is important to go beyond 'group think' and what industry players alone may want or seek to accomplish. Strategic foresight and strategic design, two emerging disciplines that have developed in response to these changes, can generate a creative framework for strategic decision making [87]. Strategic foresight is defined as the ability to create a forward-looking view and to use emerging insights in organizationally useful ways [88]. It also refers to seeing the future in different ways and imagining different possibilities through scenario building — based on trends and uncertainties — to fabricate plausible futures [90-92].

A rapidly changing context requires a change in how we tackle sustainability issues. And an increased need to recognize likely problems, ideally before they arise. The strategic foresight and design disciplines are interconnected in both theory and practice to provide sustainable solutions [89]. Strategic foresight combines the processes of scanning the environment in search of new events, analyzing the driving forces of change, and then applying anticipatory techniques to elucidate the evolution of changes and their consequences in order to help organizations better deal with uncertainties [93]. Foresight and design can complement each other in the development of longer-term visions, and they can inform strategic decision making for plausible future scenarios [89]. Integrating foresight and design is a critical process for anticipating change from the external environment that can have implications for decision makers and quality of decisions they make [91]. Foresight allows us to better conceive the plausible future context for design and design ideas, in order to provide future solutions [89]. Foresight and DT complement each other and allow us to explore alternative futures that hold fresh new perspectives [89], and opening up the range of stakeholders further increases the likelihood of success.

4.1 The foresight design thinking framework

We can investigate how the procedure can prompt organizational learning about the unpredictability of the future thanks to the developing field of design-driven foresight, which combines the use of design and foresight methods to produce more immersive, experiential, and compelling representations of the future [94]. The approach of foresight and DT was proposed at the 2014 Oxford Futures Forum. The integration of scenario planning and DT was defined as a new mode of thinking for achieving long-term sustainability. Innovation derives from how we use scenario planning and DT as uniquely human abilities to innovate for the future [95]. For the integration of DT and the foresight framework, the author suggests the deployment of DT, an iterative cycle process of empathizing, defining, ideating, prototyping, and testing [96], in a strategic reframing of the Oxford Scenario Planning approach [86]. Considering DT as a human-centered problem-solving approach, the author also suggests opening up the range of stakeholders, and methods being put in place to help ensure that they have a voice.

Innovation arises from the interchange between divergent and convergent thinking. Experiential learning of design-driven foresight can assist in the strategy articulation processes for innovation that arise as stakeholders experiment with various exploitation pathways and move through alternate phases of divergent and convergent thinking [94]. These alternating divergent and convergent thinking processes are key components of DT and involved in envisioning plausible futures. Divergent thinking involves generating multiple possibilities and expanding points of view, and convergent thinking involves narrowing a set of options and adopting a scoping perspective. The FDT model focuses on the interconnections between reframing and the reperception cycle according to divergent and convergent thinking.

Scenario research is a rigorous and practical interactive inquiry process, which can be used to enable stakeholders to frame and reframe the existing context and challenges [86, 97]. Scenario planning helps stakeholders reframe contexts and challenges by stepping out of the business-as-usual mindset [97]. To enable reframing using the scenarios approach, strategic reframing invites stakeholders to challenge existing assumptions and to think the unthinkable about future possibilities, which is critical in situations where the context for problem-solving has high impact and high uncertainty [97]. Reframing encourages stakeholders to deviate from current institutionalized frameworks in order to extend and challenge their beliefs and mindsets, and to create alternative frameworks for plausible futures [97, 98].

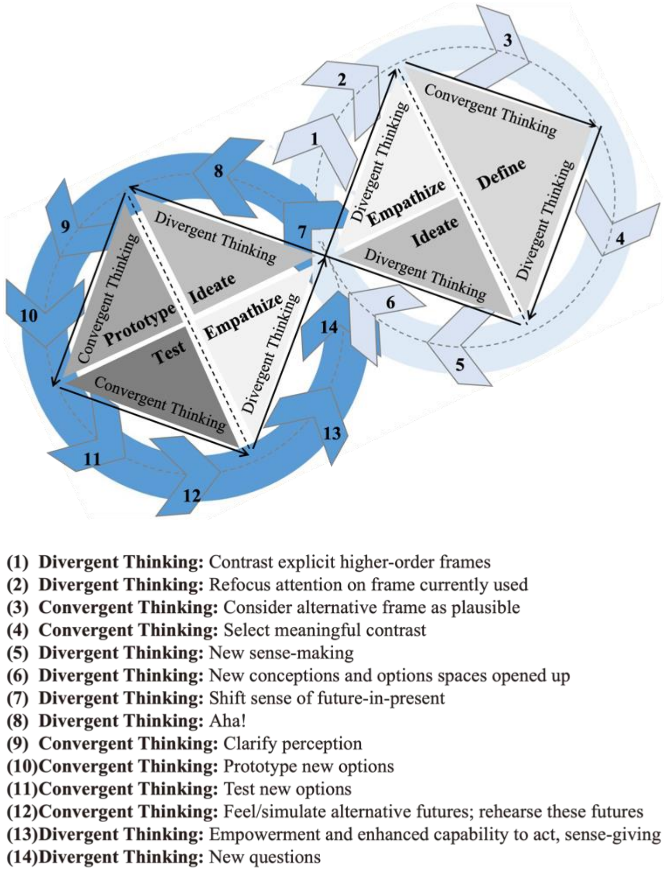

Figure 3. Foresight design thinking (FDT) model

The FDT model integrates DT and the scenario planning framework by focusing on divergent and convergent thinking. Figure 3 shows the discrete stages that are carried out in an iteratively process; the phases are detailed as follows:

Phase 1: 'Empathize' includes (1) divergent thinking: contrasting explicit higher-order frames; and (2) divergent thinking: refocusing attention on the frame that is currently used.

Phase 2: 'Define' includes (3) convergent thinking: considering an alternative frame as plausible; and (4) convergent thinking: selecting a meaningful contrast.

Phase 3: 'Ideate' includes (5) divergent thinking: new sense-making; (6) divergent thinking: opening up new conceptions and options spaces; (7) divergent thinking: shifting one's sense of future-in-present; and (8) divergent thinking: "aha!"

Phase 4: 'Prototype' includes (9) convergent thinking: clarifying perceptions; and (10) convergent thinking: prototyping new options.

Phase 5: 'Test' includes (11) convergent thinking: testing new options; and (12) convergent thinking: feeling alternative futures; rehearsing these futures.

Phase 6: 'Empathize' includes (13) divergent thinking: empowerment, enhanced capability to act, and sense-giving;

and (14) divergent thinking: new questions.

The FDT model provides foundational ideas that underpin the practice of scenario planning and DT. TUNA conditions require new approaches to sustainability and an explicit and flexible sense of the future. It can be enabled by contrasting plausible, alternative future contexts through a cyclical process of reframing and reperception repeated over multiple iterations [86]. Any situation that is thought of has already been "framed." Reframing occurs through strategic conversations that cover new ground, accept disagreement, and turn it into a resource facilitate reframing. Reperception occurs when individuals have a sense of how the future frame feels and the possibilities it presents (or close down). The cycle of reframing and perception is what leads to the "aha" moment of impact [86].

Considering the cyclical process of reframing and reperception, future space that is orthogonal to the timeline is added. The vertical "upframing," which includes the "bigger image" and generates fresh "space," reflects the width dimension. We must shift our focus and evaluate the larger context of our current situation while also moving along the time dimension, that is, we must take into account the future context, in order to reach this new area (s) [87]. Following that, “downframing” allows us to immerse ourselves in that possible future context and rehearse the actions and reactions that stakeholders might engage in under each plausible future context. These immersive experiences provide us the opportunity to reflect on our predicament, reevaluate our alternatives strategically, and create a fresh environment for the design and experience of something better [87].

Finding "the right answer" to "the problem" that we face is not the motivation behind FDT model. Instead, through a process of exploration, interactive and immersive learning, and creativity, focus is shifted to reconsidering assumptions and to posing better questions. A unique skill that helps us find new opportunities and additional, better options is reframing approach. A move from a reactive to a pre-active mindset that encourages strategic innovation can be made possible by more explicit and more adaptable understanding of the future [86].

5. DISCUSSION

In order to realistically have a chance of achieving a sustainable future, it is important that we restructure our innovation process by creating a holistic package for future needs that better accommodate future requirements [99]. Innovations are the key to the success of SBE solutions. However, many innovations are being set up around existing contexts and existing solutions, and often underrepresent the thoughts, insights, and opinions of those most at risk. Those solutions that have worked in the past and that experienced success are the basis for a positive vision of the future, and it is on this basis that decisions are being taken. Unfortunately, many existing insights cannot answer future questions [99]. Additionally, some of those insights may miss part of the bigger picture by failing to adequately tap into the knowledge that is available. In the TUNA world, there is often no direct path to successful outcomes for sustainable solutions. Dealing with sustainability addresses all the difficulties a wicked problem implies [100] that presents many unknown challenges and opportunities. Approaches to framing problems and imagining solutions for future sustainability must be adjusted along the way, based on an iterative approach [39]. The more iteration loops of action and reflection there are, the faster innovative outcomes can be developed [39]. It is also necessary to highlight that sustainable approaches are often more financially beneficial to a wide variety of parties than the ‘business-as-usual’ approach. [1, 2]. Sustainable approaches are also far more likely to drive innovation [1, 2].

The significant transition and systemic change of sustainable practices within the built environment require a more disruptive form of innovation [101], one that places sustainability first. This systematic literature review indicates that research regarding DT for innovation in SBE is challenged by the question of how to identify new contexts and new solutions for future-oriented sustainability. The sustainable development literature indicates that successfully addressing the critical challenges of the future necessitates better knowledge of how to confront and respond rapidly to the unprecedented consequences of environmental crisis [101], and to better recognize the likelihood of such events. To develop an innovation framework that responds to these future needs, it was posited that foresight is directly involved in innovation for SBE. The integrated framework of DT and foresight contributes to the study and development of sustainable innovation. Foresight helps us expand time spans, giving us a broader understanding of how different plausible futures might unfold. DT emphasizes the human’s perspective and pays attention to the development of innovations that meet the needs of the future users [99]. An integrated structure based on these two approaches can facilitate new perspectives and allow us to develop new solutions, based on a future-oriented approach [99].

Plausible future scenarios are challenging for SBE research. This review therefore suggests the combination of future thinking with scenario planning and DT to create a new approach for sustainable innovation. The results indicate that the DT approach for innovation has rarely been investigated in SBE. Although the previous works are evidence of the application of DT methodologies and tools, only some of them consider DT as an approach for innovation that focuses both on future-oriented and sustainability perspectives. In response to the research gaps identified by this systematic review, a new model of DT is proposed for future research, which encourages the practical application of DT in sustainability and the inclusion of a wider range of stakeholders who can constructively work together. In this regard, this new approach to DT for innovation in SBE, using the FDT model, offers a holistic context that illustrates the applicability of a conceptual model combining the DT approach with foresight, with the goal of contributing to built environment practices.

6. CONCLUSIONS

There are many widely recognized global environmental problems related to the built environment. This paper elucidates the connections between DT and sustainability that can be developed and refined to help address such issues, and how such an approach can be refined. This review presents an approach intended to support the development of SBE, and is intended to provide a steppingstone for identifying new methods for using DT for innovation in SBE. The purpose of this article was to highlight, identify and analyze the practical applications of DT for innovative and sustainable future solutions in the built environment and highlight areas for future development. Based on the systematic critical literature review undertaken, it was found that sustainable solutions require an integrated DT and foresight approach to enable innovation. It is also indicated that a wider range of stakeholders should be brought onboard to develop solutions more effectively. Innovation is a critical factor in addressing future challenges related to sustainability, and we urgently need to rethink how this can be undertaken. The combination of DT and foresight works to broaden the horizons of this research area, systematically and proactively addressing future challenges for human-centered design, which are concretely translated into feasible solution innovations for the built environment. Thus, the model of FDT also complements the application of DT for sustainable innovation in this research field and provides a fresh perspective on what can be achieved.

The author hopes that the findings of this work will benefit the development of DT and our understanding of its value to SBE.

In future research, the practical applications of this proposed approach need to be tested and proven. It is particularly important to further investigate and explore the potential of this approach, and also its limitations. One limitation is that the future is characterized by uncertainty; as such, this approach is based on assumptions of what people might need in the future, and the more extreme our proposed scenarios, the more difficult it often becomes to test and iterate the solution innovations. We do, however, have indicators of the directions in which things may head which can act as a starting point to develop realistic solutions. Tools and approaches should be developed to lower the application barriers and improve the quality of the outcomes. With this in mind, this framework identifies relevant fields for future SBE, and it provides an approach that will be critical to advancing the study of DT in relation to sustainability. Despite its contributions, this review was limited by a number of factors, including the fact that dataset was retrieved from only the Scopus database. The selection criteria, whereby certain keywords and English language only articles were used, also presents some limitations. Future research should consider the use of DT for innovation in SBE more broadly, across various significant databases; this will improve the research findings and expand the contribution of DT for SBE. It is proposed that future work should be undertaken to assess the validity of the proposed measures, versus traditional approaches, in real-life scenarios.

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