Building Information Modelling (BIM) and the Impact on Landscape: A Systematic Review of Evolvements, Shortfalls and Future Opportunities

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ABSTRACT

The last decade has notably witnessed a major impact on our climatic characteristics and way of living across urban and rural areas. Following the intensified effects of the climate crisis as well as the crisis of the COVID19 pandemic, this paper aims to cross silos and explore how the sectors of landscape, digital transformation and the built environment can support a resilient future. In the built environment, the impact of digital tools such as Building Information Modelling (BIM) can be recognised across many processes to deliver better value, improve productivity and drive innovative solutions. It can however be noted that most efforts have looked into the impact of BIM at a micro scale (e.g. buildings and developments) with limited focus at the macro scale (e.g. landscape design and climate change). This paper focuses on the digital technology innovations through the lens of the landscape and the exploration of how such tools could contribute to the form of planning and landscape design. It aims to lay a critical review of the impact of BIM on the landscape with insightfully pointing out evolvements, shortfalls and future opportunities.

The paper adopts a hybrid approach that includes a systematic selection of research papers focusing on landscape with particular emphasis on climate change, planning and urban design between 2010 and 2021. Findings suggest that, with relation to BIM's impact on the landscape, most efforts have focused on planning and the small residential scale. Findings also showed that there are limited efforts to investigate landscape design and urbanism and the ways in which digitalization can support sustainable development in open spaces. The area of climate change is significantly overlooked within BIM, raising concerns on the lack of current research on such a critical topic. Using the knowledge from BIM technology, the study provided evidence on the correlation with the landscape and climate change. Evidence demonstrates there is limited connection between BIM and landscape and therefore the study discusses how such tools can improve the understanding of the landscape idea as well as support the creation and visualization of environmentally friendly landscape designs. Future work includes looking into many of the highlighted trends as a result of the study with further investigation on the role that stakeholders can play as part of the digital transformation on landscape.

1. INTRODUCTION

The interest in future climate and the impact on our cities and landscapes has increased over the past decades due to the various environmental changes and extremes evolving at a global scale. It is now scientifically acknowledged that several variables such as deforestation, Greenhouse Gas Emissions (GHG), ecosystem changes, flooding, drought, rising temperatures, and so many more environmental issues are a result of the climate crisis (Carter, Cavan et al. 2015, United_Nations 2015, IPCC 2018) and that unfortunately, there is a significant anthropogenic contribution to this (Dhar and Khirfan 2017).

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The effects of climate change and natural disasters have always affected the landscape, but it is only recently that spatial strategies are strongly seen as the way towards a resilient future. Landscape, urban design and planning are now taking a more prominent role, especially as cities and urban conurbations have started shifting their visions and taking more strategic approaches to deal with climate change (Bulkeley, Broto et al. 2011, Nikologianni, Moore et al. 2019, Nikologianni, Moore et al. 2020). Especially, urban design and planning policies can reduce the vulnerability of cities to environmental risks. With the landscape seen as the broader umbrella of spatial strategies, urban design and planning focus on the city and town scale. Even though approaches and policies have started shifting, a big part of these disciplines are still operating in silos, without the interaction required between landscape architecture, planning and urban design to create wholly resilient cities. Better urban planning systems and tools are needed in response to climate change and despite all the steps forward, there is still a silo approach between planning tools and landscape (Blakely, (2007). In addition, successful urban design is key for the improvement of health of city's residents as well as increasing numbers of walkability, cycling and engagement with open and green spaces (Bahrainy and Khosravi 2013).

For over a decade, the advent of digitalisation in the built environment sector has supported many aspects across the whole life cycle (Theiler and Smarsly, 2018). Building Information Modelling (BIM) can be recognised as one of the most solidified digital technologies that revolutionised many processes in the built environment. In its broader context, BIM can be defined as a collaborative approach underline by use of technology to support centralised exchanging, sharing and updating data in a project (Demian and Walters, 2014). This has indeed enabled a more effective coordination and collaboration for the stakeholders involved in working on an integrated model (Ghaffarianhoseini *et al.*, 2017; Mayouf et al., 2014). Through the adoption of BIM, all information can be updated using common data environment, which can be accessed by all stakeholders involved (Dawood et al., 2009; Liu et al., 2009). This will benefit all phases of a project lifecycle, such as information management in construction sites, which commonly faces issues with managing the exchange of information, (e.g. daily safety reports), generated from various sources, that might contain overlapping information (Chen and Kamara, 2011; Lee et al., 2018). Within the context of landscape, it can be stated that contribution and value of BIM is considerably limited, and difficult to be determined when compared to research efforts that focused on BIM impact at a building level. This can be reasoned by several factors that exist due to nature landscape that it varies depending on regions and countries, difficulty to access/obtain databases of areas and infrastructures and also the associated cost implications (Hallgeir et al., 2018).

This paper underlines the connections between Building Information Modelling (BIM) and the landscape with direct focus on planning, urban design and climate change. It expands on the distinctions of BIM and the Built Environment and reviews the pace of technological advancement in relation to buildings as well as open and green spaces. The paper systematically looks into the extent of BIM research in relation to landscape in order to portray more clarity toward future directions for research. In order to achieve its objectives, this review discusses the findings of a systematic selection of research papers focusing on landscape with particular emphasis on climate change, planning, urban design and BIM between 2010 and 2021. The three factors (planning, climate change and urban design) were selected following initial research revealing the most significant parts for future resilience and the areas BIM has interaction. The detailed process is explained in methodology. Therefore, the aim of this paper is to systematically review the state-of-the-art on research conducted with relation to BIM for landscape in order to draw a more informed utopia into the contribution and value made by digital tools on different areas (planning, urban design, climate change) within the landscape. The paper commences with introducing these fundamental concepts and the ways in which they relate to digital tools and specifically BIM. The methodological approach of a systemic review, together with the findings, a discussion and conclusion on what needs to change follow.

2. METHODOLOGY

As discussed above the goal of this paper is to systematically review the state-of-the-art in relation to BIM within the landscape and draw a more informed utopia into the contribution and value of the digital tools within the landscape field. This paper draws upon research which made use of Systematic Literature Review (SLR) as an approach to assess existing research on BIM role for landscape with a focus on three main areas: climate change, planning and urban design. SLR is considered as one of the robust processes that aims toward minimising bias through transparent and meticulous literature search (Thome et al., 2016). The review included formulating research questions, has identified relevant publications, assessed quality of the found studies, and interpreted the findings against dimensions related to each of the three landscape areas in this research. For the SLR conducted in this paper, SCOPUS database was used to gather relevant peer-reviewed journals and conference proceedings. Furthermore, an additional scouting on the relevance between BIM and the landscape as well as the three areas selected has been conducted (see figure 1). The diagram reveals the interrelation of the selected areas with BIM and evidences the lack of connection, justifying the decision of this research to work on these thematics.

2.1. Research Questions

In this research, two research questions were formulated based on the screened literature on BIM for landscape:

Q1: What are the landscape areas that BIM has contributed to, and using which methods?

The objective of this research question was to identify how BIM has been contributing to landscape areas, what methods were used, and interpret how the paper correlates to one or multiple dimensions within each of the three landscape areas.

Q2: What are the research shortfalls within BIM for each of the landscape areas, and what are the recommendations for an improved impact of future BIM research within the landscape?

The objective of this research question was to highlight shortfalls of BIM for landscape looking at each of the three areas, and more importantly, to identify recommended directions for future research within BIM for landscape.

2.2. Database and identifying literature

The use of SCOPUS database is rationalised by its vast inclusion of peer-reviewed journals and conference proceedings related to BIM research across various areas within the Built Environment. SCOPUS also allows to look for document titles, abstracts, and keywords with relevance to particular areas of research from database of over than 41,000 research publications (Harzing and Alakangas, 2016). Hence this database allows for richer enquiry into research outputs with relation to BIM for landscape, and allows for further focus into the three areas within landscape.

This paper focuses into BIM for landscape relevant research between 2010 and 2021. The rationale behind this time frame is that BIM-relevant publications in the built environment began to take-off from 2010. In order to conduct informative search, SCOPUS search tool was used to look for document titles, abstracts and keywords that relate to the selected areas of climate change, planning and urban design. Simultaneously, it was investigated BIM, Building Information Modelling / Modelling and Building Information Model (why? Whats the difference? Could you explain?). Below are the SCOPUS queries used to conduct the search:

- (TITLE-ABS-KEY (bim) AND TITLE-ABS-KEY (landscape) = 170 results

- (TITLE-ABS-KEY (bim) AND TITLE-ABS-KEY (landscape) AND TITLE-ABS-KEY (planning*)) = 48 results
- (TITLE-ABS-KEY (bim) AND TITLE-ABS-KEY (landscape) AND TITLE-ABS-KEY (climate AND change)) = 5 results
- (TITLE-ABS-KEY (bim) AND TITLE-ABS-KEY (landscape) AND TITLE-ABS-KEY (urban AND design)) = 36 results

Total number = 259 results

2.3. Assessing quality of the results

In assessing the quality of the results found, many processes were conducted to identify relevant literature that suited the scope of the research. research (see figure 1). The methodological decisions are represented in the diagram and explained below.

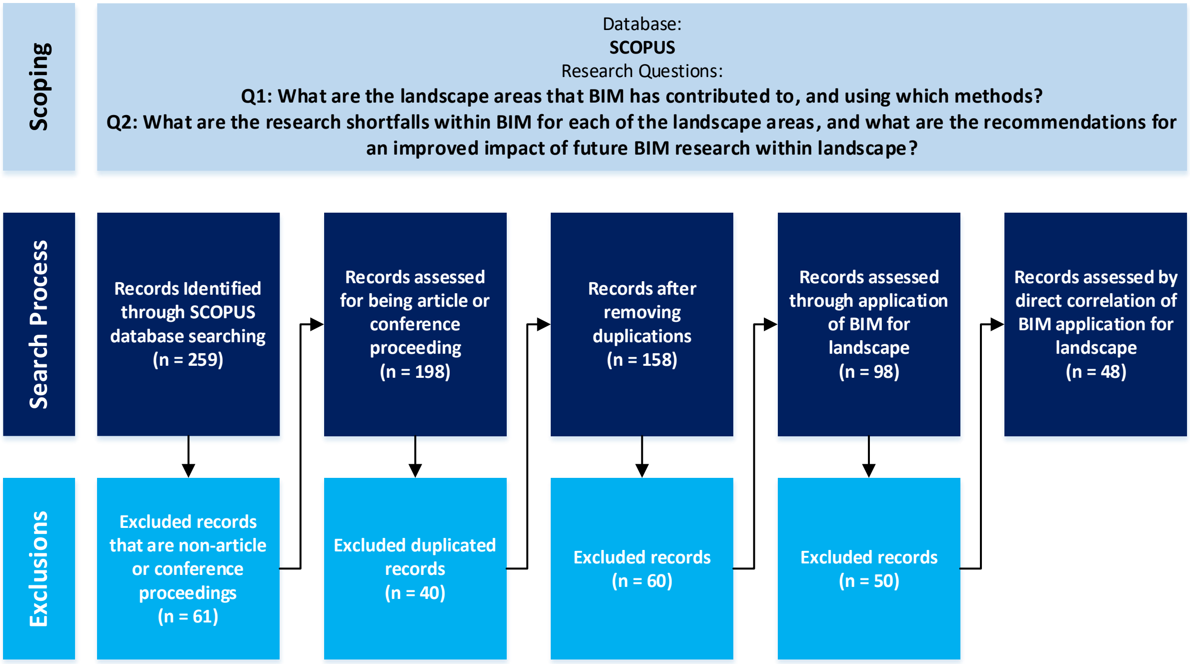

Figure 1: Flowchart of the literature review selection process

The initial process in assessing the records' quality was to remove non-article or conference proceedings. In addition to the previous, any publication not in English language was also excluded. After removing non-article or non-conference proceeding manuscripts, 40 duplicated results were removed, which was done through cross-referencing results of 'BIM and Landscape' and the other three search scripts. The following screening process included assessing of the remaining records through titles or abstracts to indicate which ones focused on BIM for landscape in general or BIM for any of the three areas within landscape (planning, climate change, urban design). The final step was to investigate records that directly correlated with BIM and landscape with clear indication in findings of the research conducted. The significance of the final step was to provide a clear reflection of research efforts that falls within the focus of BIM for landscape. More importantly, this also allows the authors to provide a more informative interpretation of how each of the papers relates to one or more landscape areas.

3. LITERATURE REVIEW

This section focuses on key themes to set the scene for concepts relevant to the research, and to identify where this paper can contribute. It discusses the ideas of landscape, climate change and urban design as well as current challenges in relation to digitalization. Aiming to explore links between landscape and BIM technology, this section discusses the concepts of landscape, climate change as well as some of the current challenges to date. The concepts of urban design and planning sit under the umbrella of landscape while climate change is one of the most imminent threats of our land and lives. While the research is set out to identify connections between digital tools such as BIM and the landscape, that would be less effective if the three key themes were not examined in details. This paper does not have a focus on definitions, but sets the scene on how landscape is perceived in the professional and artistic field, as the authors recognize the necessity of giving some background information on the origin of the term. Dealing with landscape and digitalization, it is significant to understand landscape from a broader perspective if we are to explore how digital tools and media can depict this.

3.1 Landscape: Concepts and Approaches

It is accepted that the term 'landscape' has many approaches and multiple meanings either referring to a tract of land or its visual appearance through paintings and designs. Landscape is often linked to a specific territory, a geographical region or a historic area shaped by people (Antrop and Van Eetvelde 2017). It probably originates from the Dutch language, when in the early thirteenth century, 'lantscap', 'lantscep' or 'landschap' was used to describe a land region, later adopted by Germans as 'landschaft' (Antrop and Van Eetvelde 2017). This paper acknowledges that landscape can be seen in many ways and scales, but it accepts that formal definitions given much later by conventions, such as the cultural landscapes in the UNESCO World Heritage Convention as well as the European Landscape Convention, are probably the most appropriate to date as they embed several angles of the term. The formal definition of landscape given in 1992 by UNESCO, added 'cultural landscape' as a new category on UNESCO's World Heritage List (UNESCO 1992). In addition the European Landscape Convention (ELC) describes landscape as an area ''perceived by people whose character is the result of the action and interaction of natural and/or human factors'' (Council of Europe 2000).

Antrop and Van Eetvelde, examining the difference between land and the landscape, state that 'land' refers to terrain, territory and soil, while 'landscape' is linked to 'organized land', a representation of a scene of action and activity of the people who live nearby (Antrop and Van Eetvelde 2017). Landscape also expresses a visual interpretation and it does link to an ecological identity (Antrop 2001), however this approach often creates several forms as to how landscape is perceived and how we can work with it on a spatial basis. Olwig (1996) argued that landscape ''need not be understood as being either territory or scenery; it can also be conceived as a nexus of community, justice, nature, and environmental equity […]''. Following a different approach Selman (2006) stated that ''landscapes may derive from a combination of natural human factors, but equally they can be purely socially or purely naturally produced, and in the latter case there need to be no explicit cultural component''. More than two decades ago, Cosgrove (1998) was suggesting that landscape was ''pre-eminently the domain either of scientific study and land planning, or of personal and private pleasure''. However, Shannon and Smets (2010), argue that 'infrastructural development is not merely a technical matter to be left to traffic planners, engineers, and politicians, but a crosscutting field that involves multiple sectors and where the role of designer is essential', embracing the importance of quality and the impact that this can have for a strategic development. For these reasons, this paper argues that a

successful creation of landscape-focused digital tools needs the design as well as the scientific approach and discusses their impact on the landscape profession.
This paper is alligned more with Cosgrove and their view that ''the landscape idea represents a way of seeing'' (Cosgrove 1998) and perhaps this dimension is where the link with digitalisation such as BIM comes. According to Baker (2014), it is crucial to 'capture the spirit of place' to demonstrate an understanding of a landscape through direct experience and research into its background and truly understand the landscape before expressing its qualities and amenities. What is often called 'sense of place', 'genius loci' or spirit of place (Norberg-Schulz 1980, Jivén and Larkham 2003, Moore 2009) has significant links with landscape quality, but its integration in large scale planning mainly responds to the concepts of 'scenery', 'scenic beauty', 'environmental elements', or 'cultural landscapes' (Ewald 2001) without necessarily demonstrating more detailed spatial characteristics. This research wonders how this is possible through digital technologies with direct focus on BIM and to what extent it can support representing landscape areas.

3.1.1 Climate change, planning and urban design: advancements and challenges

''If you had the whole of the city designed by the best architects and you didn't do anything about the landscape you would still have a disaster" explained Sir Peter Shepheard, Past President of both the Landscape Institute (UK) and RIBA (Harvey 1987). He made the point of a holistic approach on urban design and landscape planning. Nowadays, it is as important to include climatic and environmental characteristics as well when designing at an urban and regional scale. An increase in global average air and ocean temperatures, warming of the climate system and global sea level rise, as well as widespread melting of snow and ice, are only a few of the effects of a changing climate (Gossop 2011) based on studies from the United Nations Intergovernmental Panel on Climate Change (IPCC 2018). Observations of recent severe droughts and flash flooding in Southern and Northern Europe, together with the impact of a 1.5^{o}C temperature rise (IPCC 2018) are further signs of how climate emergency can and does have serious adverse impacts on the landscapes we deal with daily as well as the future land use. Professionals across the globe are working on several scenarios on how our urban and planning design methods can be transformed, and the ways landscape architecture and BIM can support on this.

Current biodiversity and environmental challenges affect the shape of our cities, access to food and clean water, nature and the environment and therefore our health and wellbeing. Even though we have come a long way over the past decade, there is still a lot to be done when it comes to climate change and the way in which this is addressed within the landscape sector (Nikologianni, Moore et al. 2019). Feliciano and Prosperi (2011) wonder, 'are we talking about lifestyles, activities, or enterprises? Are we talking about individual or voluntary behaviour change or a policy framework that seeks to encourage behaviour change by regulatory force?' Termorshuizen et al. (2007), in order to highlight the major impact of climate change on the land, use Rio's declaration of the environment statement; 'sustainable development is widely accepted as a strategic framework for decisions on the future use of land' (IUCN 1992). However, the question remains, how can we design for a sustainable future and what can digital tools do to support this? The answer perhaps comes from the Design Council that has stated that ''good design is a key aspect of sustainable development, is indivisible from good planning and should contribute positively to making places better for people'' (DesignCouncil 2012).

Having a better understanding of the landscape and exploring the impact of the climate crisis makes it easier to predict – even if only partially - the challenge to our cities and communities as well as the significance of design solutions either these come through adaptation or mitigation. Carter et al.

explain that cities occupy a central position in the adaptation agenda and therefore the pressing nature of adaptation in cities becomes apparent (Carter, Cavan et al. 2015). Landscape understanding and visual representation are not only major areas where digital technologies such as BIM can support, but a necessity that needs to be explored for better outcomes in the fight against a changing climate.

In the past, the connection between urban design, nature and climate change was considered ''rather scant'' (Blakely 2007), but recent research makes a direct link between urban planning, adaptation and mitigation processes and the way in which these affect our cities and communities (Newman 2020). There is still a lot to be investigated when it comes to digital tools such as BIM and their connection to landscape and urban design as well as the various ways these can support the fight against the climate crisis.

3.1.2 Current Challenges facing Landscape

It is important to acknowledge that urban design and planning play a key role in the way in which cities can address climate change and adapt or mitigate several environmental challenges. Blakely (2007) has suggested that urban planning is at the forefront of addressing nature and climate change, however, and despite the rapid development of planning and design, the physical planning and the design of built environments are less covered in comparison to landscape planning interventions related to adaptation, transportation and infrastructure (Dhar and Khirfan 2017). This lack of exploration creates several challenges and delays when it comes to urban design and climate change. Even though it is broadly accepted that to reduce climate change risks, urban planning in strategic and statutory processes are needed, and that new planning legislations will have to integrate climate change impact assessments (Blakely 2007, Newman 2020), there is no coherent strategy on how this can progress. Newman (2020) explains that urban and town planning need to generate environmental sensitive urban design in order to address climate adaptation, however this study seeks to explore what the input of technology in relation to climate change and the landscape is. It is considered that the technological as well as the urban planning sides need to work in parallel to make sure a city is protected from extreme events or ready to adapt when these occur, but there is not consistent use of digital tools that can support this. Carter et al. (2015) state that ''the development of a collaborative, sociotechnical agenda is vital if we are to meet the climate change adaptation challenge in cities''(Carter, Cavan et al. 2015), but the challenge considered here is the extent to which this agenda includes technologies and digital tools. In addition, Newman (2020) states that ''adaptation is rarely conducted without a political crisis that can generate the necessary investment to change'', however recent climate extremes and disasters have demonstrated the impact of climate change to the landscape and our urban environments and therefore, the goal for this study is to highlight the role BIM can play in addressing these challenges.

3.2. BIM in the Built Environment

3.2.1. BIM: Uptake in the built environment

It can be stated that the transformation of the AECO industry (Architecture, Engineering, Constructions and Operations industry) from the traditional ways of working to a BIM-enabled modus operandi has led to BIM adoption throughout the lifecycle of a BIM project (BIM United, 2020). BIM can broadly be described as an approach to digitalise the virtual model of buildings using common data environment so that different stakeholders can input, exchange and share information collaboratively (Wen et al., 2021). BIM can be applied to different stages of the whole life cycle of a construction project including pre-planning, design, construction, operation and maintenance. BIM-enabled projects entail the ability of collaborative working mechanisms through exchanging and sharing data using a variety of file formats (Demian and Walters, 2014). Amongst the variety of file formats, Industry Foundation Classes (IFC) is recognised as the commonly used in data exchange between different stakeholders (Edmondson *et al.*, 2018; Patacas *et al.*, 2016). This has indeed enabled a more effective coordination and collaboration for the stakeholders involved in working on an integrated model (Mayouf et al., 2014; Theiler and Smarsly, 2018). More importantly, this allowed all team members to interact during the lifecycle of the project creating information with consistent control of workflows and information detail (Karlshøj *et al.*, 2012; Lee et al., 2016; Mayouf et al., 2019). Therefore, Software companies are continually improving the limitations of IFC data-exchange files in order to make the collaboration easier and more efficient (Bazjanac, 2008; Van Berlo *et al.*, 2012; Theiler and Smarsly, 2018).

In 2018, and to standardise the implementation of BIM, ISO19650 standards were introduced so that it supports the collaborative process between different stakeholders (Richard, 2018). Over the years, research showed that BIM has supported enabling better information management by enhancing collaboration and communications between teams (Ghaffarianhoseini *et al.*, 2017). With the adoption of BIM, all information is updated on a single data base which can be accessed by all stakeholders involved (Dawood et al., 2009; Liu et al., 2009). This will benefit all phases of a project lifecycle, such as information management in construction sites, which commonly faces issues with managing the exchange of information, (e.g. daily safety reports), generated from various sources, that might contain overlapping information (Chen and Kamara, 2011; Lee et al., 2018). In a recent study by Wen et al. (2021), it was found that BIM adoption and implementation have varied over the years, and the way it is perceived played a major impact on both research and practice. For instance, from 2012, the focus has gone beyond technology-related complexities such as interoperability, to focus on BIM informatisation (reliance on information embedded in the BIM Model) and data sharing between stakeholders. In fact, developments in BIM in the last few years began to focus on the practical application of BIM on specific areas to solidify the implementation roadmap and have more tangible measures toward its role in a project (Kaewunruen et al., 2020; Wang et al., 2016). The next section elaborates further on the role of BIM within the life cycle in a project.

3.2.2. BIM: a life-cycle perspective

Inevitably, one of the main values of BIM is that it facilitates informed decision making at early stages rather than late during the execution process, which inherently reduces wastage of time and resources (Lorimer, 2011). As stated by the Construction Industry Council (2013), and as adopted from PAS 1192, the project lifecycle can be broken down into 7 phases. These include brief, concept, developed design, production, installation, as conducted, and in use. These phases can be linked to the delivery of projects. The different stages for project delivery systems were: strategy, brief, concept, definition, design, build and commission, handover and closeout, operation, and end of life (CIC, 2013). With respect to different stages, BIM models have the ability to combine graphical, non-graphical information and documentation in one file from which a user can define and visualise the components of buildings (Kensek, 2015; Morlhon et al., 2015). BIM models also offer information on how different objects and parameters interact with each other and how they are interrelated (Honti and Erdélyi, 2018). Hence, this entails data exchange files to contain more information than just simple geometrical information that are usually shown on CAD files (Bandi, 2019).

Extensive efforts by research and practice are continually featuring of BIM that can be used over the lifecycle of the project. As stated by Baldwin and Bordoli (2014), application of BIM in the design phase enables spatial visualisation and interdisciplinary coordination. BIM can also be used in design analysis for structural elements, energy modelling and simulation, and viability check of the design against the code (Czmoch and Pękala, 2014). During the construction phase, BIM enables informed decision making regarding site mobilisation and utilisation, activity sequencing, scheduling and cost estimation (Eadie et al., 2013). It can also be used in asset and facility management by monitoring, managing and reporting issues that would be linked to the building environment and components (Kelly *et al.*, 2013).

3.2.3. BIM for Landscape: Recent efforts

Amongst different stages in the lifecycle of a built environment project, landscape may be perceived as the macro lens that supports perceiving new contexts from local, regional and environmental dimensions. From a BIM perspective, it can be stated that the application of utilising integrated digital processes that support a more structured approach towards data and information management can support designers and contractors to coordinate sites (Hardin and McCool, 2015). Compared to the application of BIM at building level (micro scale), integration of landscape-related areas within BIM can be considerably limited, and this can perhaps be reasoned by several elements including the nature of landscape in different countries / regions, associated costs and difficulty to access / obtain databases of local areas and infrastructure (Hallgeir et al., 2018).

The studies on BIM within the context of landscape have progressively attempted to address multiple aspects with relation to the landscape. For instance, a recent study looked into landscape-related operations, which identified 18 problems from architects', consultants' and contractors' perspectives (Emara, 2021). The study proposed a BIM-based Model to solve top problems including the identification of building methods, costs and budgets, selection of project management teams, landscape project schedule and identifying structure system used for landscape work. However, in order to gain richer, and more holistic view of where BIM has contributed to landscape, the authors have conducted bibliometric analysis (see figure 2) that looked into publication records within the last 10 years. The analysis identified that major efforts were conducted with relation to planning and design, urban planning, landscape design and urban landscape. However, limited research has connected to environment, climate change, social and environmental aspects, urban generation and also environmental planning. As Figure 2 demonstrates, areas with larger node size (e.g. building information model-bim, bim, etc) have revealed a greater amount of literature compared to smaller nodes. In addition the distance between nodes shows more interrelation, while long distance as this depicted for climate change reveal the isolation of certain topics in relation to the rest of the themes. The papers are linked with their key topic as this is explained in the methodological stage.

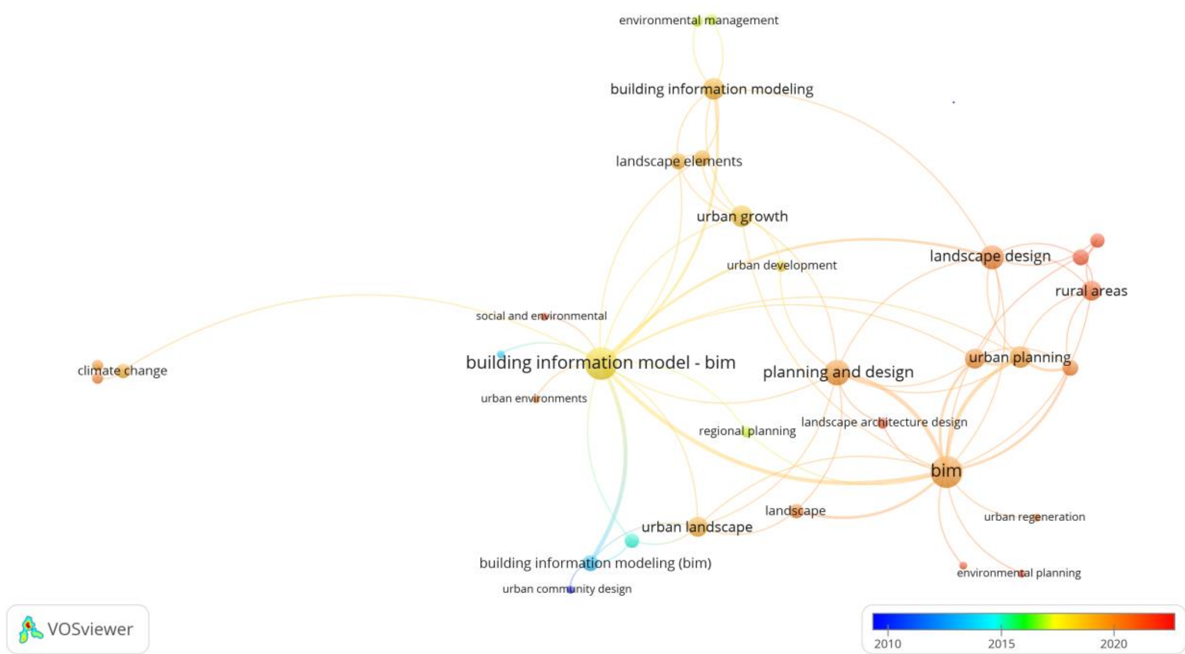

Figure 2: Bibliometric Analysis of Literature relevant to BIM, Landscape, Planning, Urban Design and Climate Change.

4. RESULTS AND ANALYSIS

The results and analysis section responds to the research questions. Following the process described in the methodology, this paper initially identified 259 results in relation to BIM for landscape and within the areas of planning, climate change and urban design. However, following an in-depth analysis and screening of the first results, only 48 papers were considered appropriate for further analysis. The table and analysis provided in this section demonstrate the literature where BIM has been interacting with the broader landscape idea and within the three areas of focus. As the landscape has a broad spectrum and provides additional information for each area, the authors have selected specific dimensions concerning each theme as these have been emerging by the 48 papers. The selected papers revealed the dimensions of 'sustainability' and 'environmental characteristics' within the climate change area. The papers revealed the dimensions of 'landscape planning', 'building methods' and 'residential areas' for the planning area. For the area of urban design, the dimensions revealed were 'infrastructure' and 'landscape design'. The response to Q1; 'What are the landscape areas that BIM has contributed to, and using which methods?' comes from Table 1, where the exact landscape areas are presented together with the findings and methods followed. It is important to clarify that even though BIM has a long standing in building infrastructure as well as planning (with a building focus), the evidence show there is no such strong link when it comes to landscape planning and design. It is also important to note that only a few papers address all three areas selected. The response to Q2; 'What are the research shortfalls within BIM for each of the landscape areas, and what are the recommendations for an improved impact of future BIM research within landscape?' is discussed in section 4.2 followed by the discussion.

4.1. Bibliometric Results

Table 1: Thematic analysis of papers on BIM for landscape areas: Climate Change, Planning and Urban Design between 2010 - 2021

Year	Location	Findings	Method	Authors	Landscape Areas		
					Climate Change	Planning	Urban Design
2021	N/A	Presenting CityGML EnvPlan ADE and new 3D information model (BIM and environmental planning)	BIM-GIS	Wilhelm et al.	X (Sustainability)	X (Landscape Planning)	
2021	N/A	Concerns of landscape and environmental conservation can be better considered during the building phase	BIM Data	Bruckner and Remy	X (Sustainability)	X (Landscape Planning) (Building Methods)	
2021	China	Applying BIM to analyse landscape design. Rural landscape planning and design scheme to improve the living standards of rural people	BIM Data	Bai		X (Landscape Planning)	X (Infrastructure)
2021	Switzerland	BIM technology in the landscape gardening industry is relatively slow	BIM Data	Zhu et al.		X (Landscape Planning)	
2021	N/A	Technologies and strategies for coding, surveying and model historical centres on urban vulnerability and risk	BIM-GIS	Ramfrez and Ferreira		X (Landscape Planning) (Building Methods)	X (Infrastructure)
2021	Austin (USA)	BIM Model can be used to support utility structure and retention system	BIM Visualisation	Luxford and Lindquist		X (Building Methods)	X (Infrastructure)
2021	India	A baseline approach for rainwater harvesting to address water scarcity issues for residential buildings and factories of the future.	BIM-GIS	Maqsoom et al.		X (Landscape Planning)	X (Infrastructure) (Landscape Design)

2021	N/A	Interdisciplinary cooperation of environmental facts for professional advances in landscape and urban planning.	BIM-GIS	Gnadinger and Roth	X (Environmental Characteristics)	X (Landscape Planning)	X (Landscape Design)
2021	N/A	Improve the rational of road engineering design schemes through the use of BIM Applications.	BIM Data	Huang et al.		X (Landscape Planning)	X (Landscape Design) (Infrastructure)
2021	Middle East	Identifying top landscape problems that BIM can support .	BIM Data	Emara		X (Building Methods)	
2020	N/A	A multidisciplinary approach towards sustainable design to address challenges of hot and dry climate (architecture, ecology and landscape).	BIM Visualisation	Briscoe		X (Building Methods)	
2020	China	BIM provided significant benefits for design and application for landscape.	BIM Data	Wei et al.		X (Landscape Planning)	X (Landscape Design)
2020	N/A	BIM has some potential support towards sustainability, modern rural architecture and smart mobility in urban development.	BIM Data	Conference Proceedings		X (Building Methods) (Residential Areas)	
2020	N/A	The paper offers an explanation of how "information" from BIM can enrich landscape models in landscape design, maintenance and management.	BIM Data	Wei et al.		X (Landscape Planning)	X (Landscape Design) (Infrastructure)
2020	Rome (Italy)	ICT tools such as BIM can support decision-making for construction processes	BIM Data	Gigliarelli et al.		X (Building Methods) (Residential Areas)	
2020	Czech Republic	The paper reveals connections of BIM models data and their data	BIM Data	Pruskova	X (Sustainability)	X (Landscape Planning)	

		exchange in the environment of Czech Republic's legislation.					
2020	Cyprus	Advantages and role in constructing 3D city models that successfully deal with every challenge in the urban landscape.	BIM-GIS	Andrianesi and Dimopoulou		X (Landscape Planning)	X (Landscape Design) (Infrastructure)
2020	N/A	3D Modelling from BIM to: Simulate different zones of a construction project to integrate residential areas and infrastructure with natural environment.	BIM-GIS	Jiang	X (Environmental Characteristics)	X (Residential Areas)	X (Infrastructure)
2020	Wales (UK)	Initiate mid to high level ontology in the urban sustainability data model through the support of BIM.	BIM Data	Kuster et al.		X (Landscape Planning)	X (Infrastructure)
2019	N/A	The paper reported from buildingSmart international working group "Site, Landscape, and Urban Planning".	BIM Data	Fritsch et al.		X (Landscape Planning)	X (Infrastructure)
2019	Italy	Presenting BIM-based lifecycle-oriented approach to information modelling and management of an existing building set in an urban historical context.	BIM Data	Lavenia		X (Landscape Planning) (Building Methods)	
2019	Italy	Exploiting challenges with relation to landscape disciplines within the context of built heritage using digital photogrammetry and 3D scanning.	BIM Data	Btelli and Balletti Brumana et al.		X (Landscape Planning) (Building Methods)	
2019	Italy	H-BIM approach for the management of historical building heritage, focused on district management (at an urban level).	BIM-GIS	Ruffino et al.		X (Landscape Planning) (Building Methods)	

2019	N/A	The study provides a valid methodology to involve landscape and urban planning in the BIM process	BIM Visualisation	Semeraro et al.		X (Landscape Planning) (Building Methods)	
2019	Hong Kong	The developed approach supported the recognition of roof top elements through linking BIM and City Information Models	BIM and Machine Learning	Tan et al.	X (Sustainability)	X (Building Methods) (Residential Areas)	
2018	Turkey	Based on CityGML schema, a 3D utility underground mapping was completed	BIM Visualisation	Buyuksalih et al.		X (Landscape Planning) (Building Methods)	
2018	China	Use of BIM simulation of the 3D terrain combined with the design to see whether the layout of the building is reasonable	BIM Data	Wei et al.		X (Landscape Planning)	X (Landscape Design)
2018	N/A	CityGML serves as an exchange format as a data source for visualisations, either in dedicated applications or in a web browser.	BIM Data BIM Visualisation	Ohori et al.		X (Landscape Planning)	
2018	N/A	Various directions how to use 3D Models of landscape to solve urban planning problems	BIM Visualisation	Danilina et al.		X (Landscape Planning) (Building Methods)	
2017	India	Presenting characterization analysis of real-time energy consumption and carbon emissions and subsequently estimates the life cycle energy of buildings	BIM-GIS	Vineeth et al.	X (Sustainability)	X (Building Methods)	
2017	N/A	Incorporate smart materials into district-scale urban building energy modelling frameworks	BIM Data	Yang et al.		X (Building Methods)	
2017	China	Garden construction process dynamic simulation and virtual	BIM Visualisation	Zuo, J.		X (Landscape Planning) (Building Methods)	

		landscape engineering construction.					
2017	Taiwan	An evaluation of energy-saving efficiency is conducted with cooling insulation of the living green shall (LGS) over the sheet metal buildings.	BIM Visualisation	Lee and Chuang	X (Sustainability)	X (Building Methods) (Residential Areas)	
2017	China	Development of Landscape Model to simulate material paving.	BIM Data BIM Visualisation	Jia et al.		X (Building Methods) (Landscape Planning) (Residential Areas)	
2017	China	Identifying relationship between materials, products to buildings by modelling energy performance of windows and facades to building using BIM system.	BIM-GIS	Yang et al.	X (Environmental Characteristics)	X (Building Methods) (Residential Areas)	X (Infrastructure)
2016	Italy	Introducing almost unknown historical and artistic heritage through multimedia visualization.	BIM Data	Amoruso and Manti		X (Landscape Planning)	
2015	N/A	The system can contextualise low energy building design in the urban energy landscape.	BIM-GIS	Niu et al.	X (Sustainability)	X (Building Methods)	
2015	Japan	Comprehensive understanding of sustainable area management from points of intuitive 3D-modeling, wides area design and environmental engineering.	BIM-GIS	Fujiwara et al.	X (Environmental Characteristic)	X (Residential Areas)	X (Infrastructure)
2015	Not mention ed	Virtual reality environments are used for architecture, landscape and environmental planning.	BIM Visualisation	Portman et al.		X (Building Methods) (Landscape Planning)	
2015	N/A	Revit enabled the development of BIM-specific functions for Landscape Architecture practices.	BIM Data BIM Visualisation	Dawood et al.		X (Building Methods)	X (Landscape Design)

2014	Taiwan	BIM can create sidewalk sections with relevant information, and this can support the government when transforming urban landscape.	BIM Data	Huan and Song		X (Landscape Planning)	
2014	USA	Engaging different stakeholders to improve decision making through identifying relationships between stakeholders' data and information	BIM Data	Briscoe	X (Sustainability)		
2014	China	Focusing on energy and architectural design.	BIM Data	He et al.		X (Building Methods)	X (Infrastructure)
2013	N/A	How can landscape architects use BIM	BIM Visualisation	Nessel		X (Landscape Planning)	
2013	China	Improve efficiency in the process of project construction: elements of analysis, meteorological data, thermal environment, light/acoustic/solar and economic.	BIM Data	Lu and Wang		X (Landscape Planning)	X (Infrastructure)
2012	Finland	Suggesting new ways to engage citizens in developing the city district vision through social media, which can inform land use and building projects	BIM-GIS	Porkka et al.		X (Landscape Planning) (Building Methods)	
2012	UK	Landscape Architecture not compatible with BIM software BIM is encouraged to be used in collaboration with GIS, ArchiCad, Land FX.	BIM-GIS	Ahmad and Aliyu		X (Landscape Planning)	
2010	Korea	Develop an integrated design evaluation tools focused on the basic design phase for urban community development based on BIM technology	BIM Data	Lee et al.	X (Sustainability)	X (Landscape Planning)	X (Landscape Design) (Infrastructure)

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4.2. Thematic Analysis: Peaks and shortfalls within BIM for Landscape

As part of this review, a thematic analysis on existing literature has been conducted. The paper has examined the interrelation between BIM and landscape areas and the extent to which this connection is reflected in academic studies. As landscape is often approached in different ways and with this paper acknowledging that, the landscape idea is 'a way of seeing', specific factors were identified to support the research. To understand how each paper was thematically analysed, figure 3 shows the process followed when examining each paper.

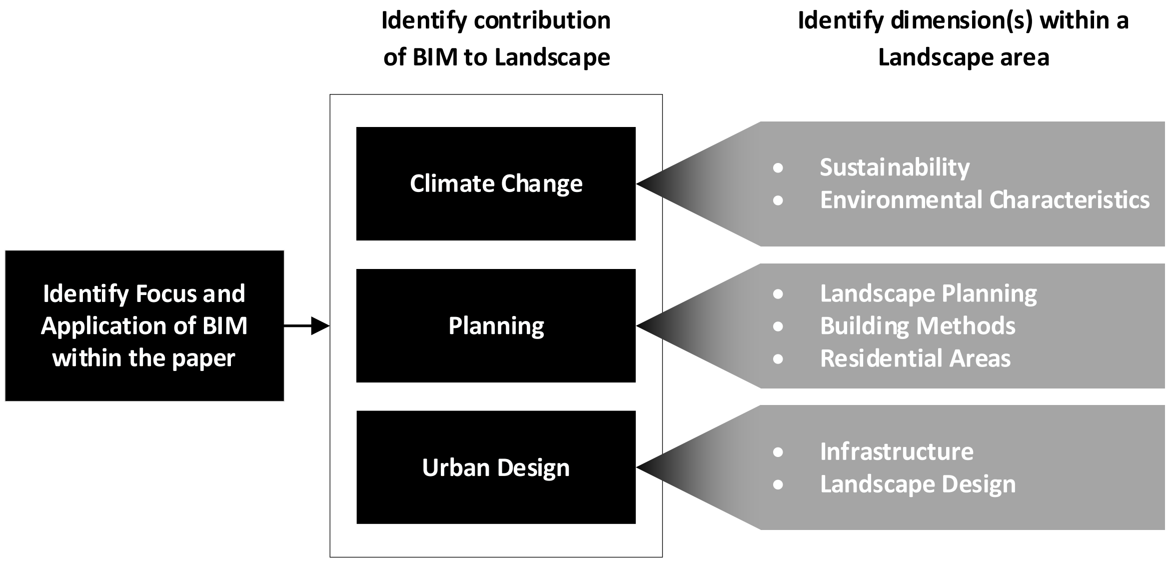

Figure 3: Process followed when examining each paper

The study was conducted analysing and interpreting the way in which BIM has been explored in relation to the landscape areas of 'climate change', 'planning' and 'urban design' and the methods used when this occurred. As per figure 3, for each of the identified papers, the authors looked into each paper and mapped the contribution of the paper to the appropriate landscape area(s) with identifying the dimensions that the paper contributed within a landscape area (e.g. sustainability dimension in climate change). This process was rationalised by the need to provide a more structured and deterministic approach to BIM for landscape. It is important to note that the review was conducted from 2010 to 2021, in a decade the authors argue there was significant interest in the development of BIM, as well as a strong focus on environmental design, planning, health and wellbeing for future resilience. In total, 48 papers that directly connect BIM with landscape were analysed. The investigation on how BIM has been contributing (if it has) to the landscape field has revealed further dimensions within the initial identification of the selected landscape areas. As shown in Table 1, each of the papers analysed has contributed to at least one or more of the areas, and specific dimensions such as 'building methods', 'environmental characteristics', 'residential areas', 'infrastructure', 'landscape planning', 'sustainability' and 'landscape design' have been identified.

Generally, initial findings (see figure 4) demonstrated that the first half of the decade 2010-2016, there is much less significant literature about BIM and the landscape, the fact that is understandable as BIM was then being developed with a focus on buildings and materials without considering landscape infrastructure. This is particularly recognised between 2010-2013 where research on BIM was more focused on asserting its value and impact during design and construction phases. Although earlier efforts in 2010 have conceptually outlined how BIM can support landscape phase, findings were complex to be validated or evaluated. This can also be reasoned by the fact that majority of BIM-based research did not engage landscape specialists, hence research into BIM for landscape did not advance with a sustained pace. The study conducted in 2010 (Lee et al. 2010), at the time, can be considered as one of the key studies within BIM for Landscape, but due to the vast technological pace of BIM, maintaining focus on landscape as a whole was complex. Hence later studies on BIM for landscape were often dictated by available BIM tools. To illustrate this, for instance, many studies between 2013-2015 have focused on planning and in particular 'building methods' as many BIM technologies (e.g. 4D, 5D) were focused on the design and construction phases. This recognises that research within BIM for landscape was more technologically led, and this did not support recognising BIM benefits for landscape holistically. It can be claimed that one of the main motivations that expanded BIM outreach following 2016 was the vast uptake across many regions, especially UK (e.g. Kuster et al., 2020), China (Wei et al., 2020) and Europe (e.g. Btelli et al., 2019). These geographical differences can be reasoned by mandates introduced such as the UK Mandate in 2016, and also BIM standards and protocols in Europe and different parts of Asia.

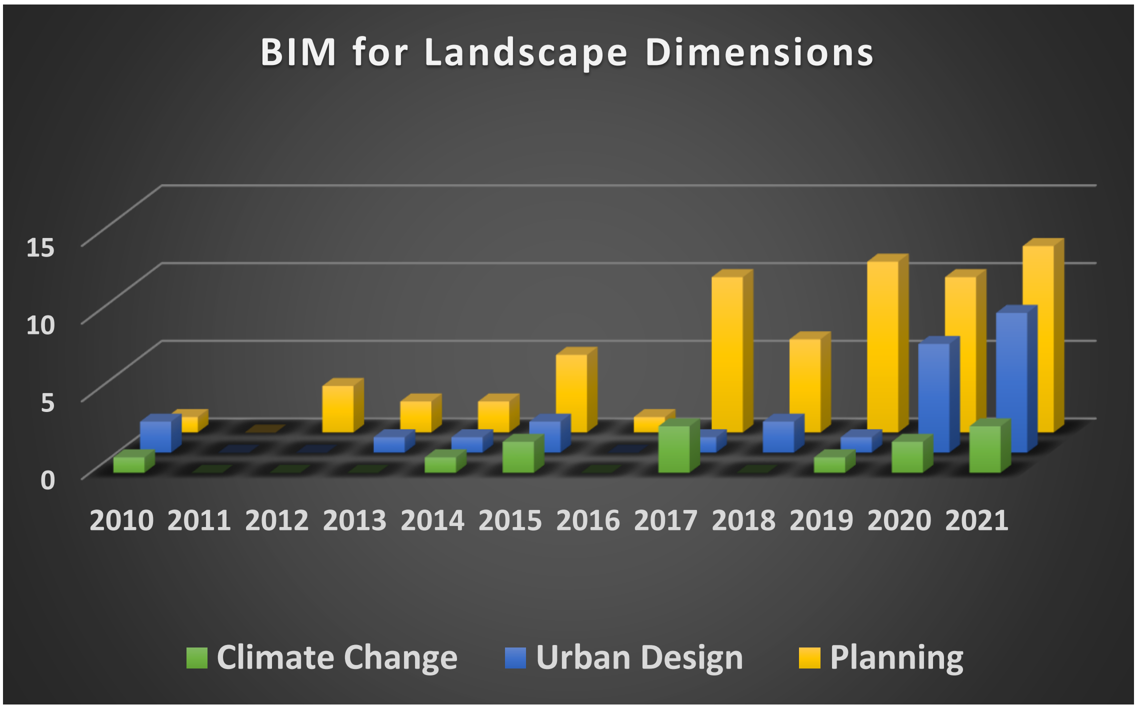

Figure 4: Research uptake of BIM for Landscape between 2010 – 2021.

In order to provide better and richer insight into research within BIM for landscape, figures 4-6 are provided to show which dimensions within each of the landscape areas in this research. Although number of papers is considerably low, recognising which dimensions existing research have focused on will inform future research, and prompt under-researched landscape areas. The research reveals that BIM has mostly contributed to 'planning' (see figure 5) with significantly less contribution to 'urban design' (see figure 6). Table 1 also shows that in 23 cases, research was focusing only on one factor, for example 'BIM and planning', and there are fewer cases where investigations were carried out with a much more multidisciplinary scope (e.g. 'BIM and planning' and 'BIM and urban design'). Amongst the three landscape areas, planning has received consistent attention with further increase from 2016 onwards. Within planning, it was found that most focuses were 'landscape planning' followed by 'building methods' with a very small link to 'residential areas'. More importantly, few cases demonstrated cross-disciplinary investigations and explored the impact of BIM tool in all 'landscape planning', 'building methods' and 'residential areas'. Such findings show that, even though landscape was initially considered as an area of interest for digital tools, the research provided by the papers was focusing on the building and residential elements that BIM had a lot to contribute to instead of green and open spaces. It is also important to note that, with respect to planning dimensions, from 2015/2016, there is a more tangible recognition of BIM tools portraying context and/or case-based evidence, which illustrated advancement in the planning area from BIM perspective. As for research on BIM for Urban Design, it can be stated that efforts began to increase in the past two years (2020 and 2021) with more emphasis on the dimension of 'infrastructure' compared to 'landscape design', a result that is justifiable as infrastructure has a broader definition while landscape design requires a specific selection of spatial projects. Compared to planning, research on BIM with relation to urban design can be considerably limited and mostly associated with studies that elaborated on planning-related dimensions.

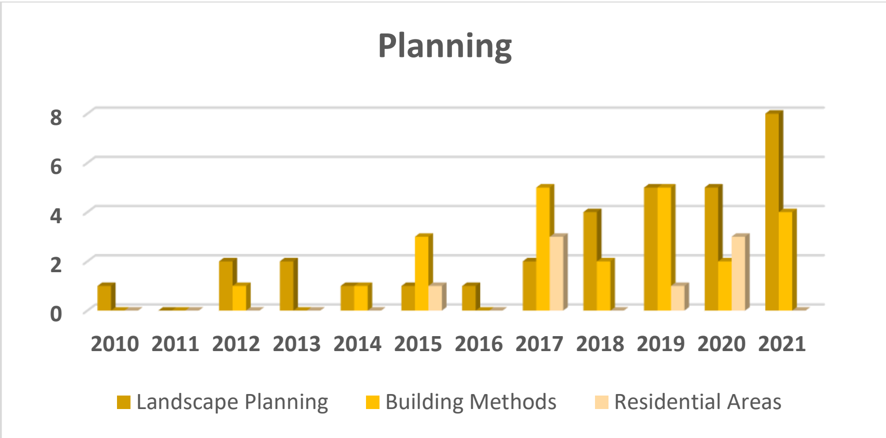

Figure 5: Research on BIM for different dimensions across planning between 2010 – 2021

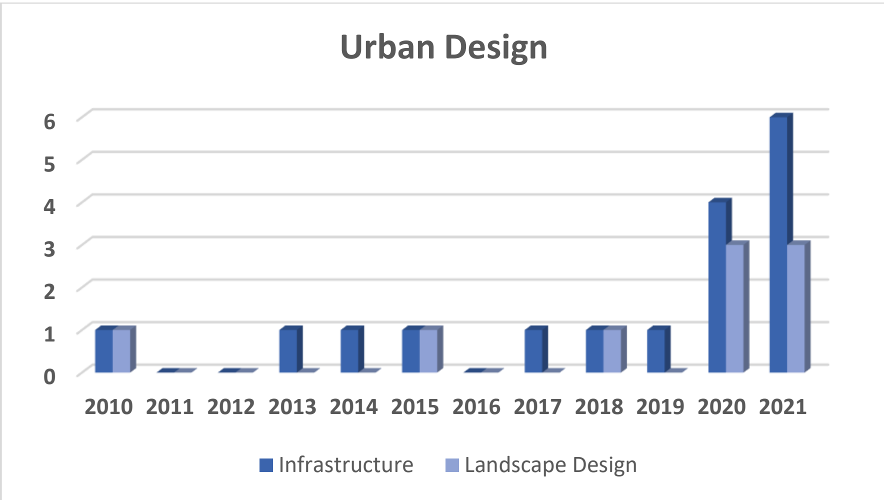

Figure 6: Research on BIM for different dimensions across Urban Design between 2010 – 2021

Another very significant finding is the connection of BIM with climate change, within the scope of landscape. As demonstrated on Table 1, it is only recently that environmental concepts and climate-focused literature has made its appearance with an interest to BIM. This is considered a significant finding since the aim of this paper is to explore the impact digital tools, such as BIM, have in the fight against a changing climate and how they can support future resilience in cities and regions. The emerging areas of 'climate change' and 'environmental characteristics' have started making their appearance from 2017 onwards (Table 1). The small number of studies demonstrates the limited and often isolated emphasis of digital processes such as BIM in relation to strategic scale and environmental characteristics. This finding enhances the questions raised by this paper on the role BIM can play to support global challenges such as climate change within a strategic landscape scale.

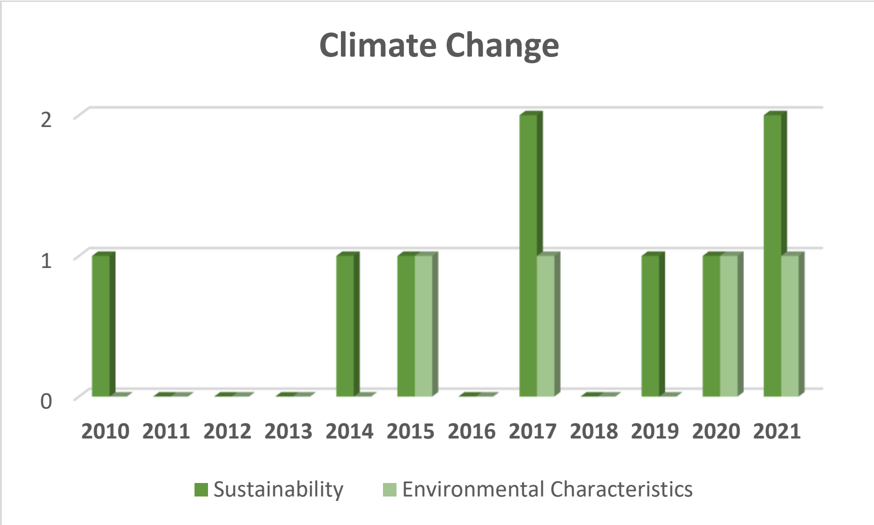

Figure 7: Research on BIM for different dimensions across climate change between 2010 – 2021

5. DISCUSSION AND PRACTICAL IMPLICATIONS

5.1. BIM for Landscape: Opportunities and Threads

Findings from this analysis has so far highlighted the fragmentation and isolation of digital concepts and tools with the landscape approach. Even though this paper investigates ways in which BIM can support and better equip landscape design to overcome the challenges of large-scale design (city/region), data shows that a lot needs to be done to increase efficiency. . Several gaps in relation to the concepts of landscape and BIM have been identified. These disciplines operate in an isolated way, despite the efforts of some professionals to use digital tools for evaluation and assessment of landscape areas. The realization of a limited number of available research about BIM and the landscape needs to be highlighted. Even though BIM is a key tool for planning, infrastructure and buildings, there is no such evidence to suggest its impact on landscape architecture and especially on landscape design and climate change.

This paper argues that BIM and other digital tools (such as Pathfinder, iTree, Vectorworks) have a lot to contribute to landscape. They could improve the understanding of the land (modelling), identify climatic and environmental characteristics, and support on landscape design for future resilience. However, the lack of findings suggest that there is a need for this field to be further developed and for BIM to accommodate the requirements of landscape. Accepting that other tools have been developed further in relation to the landscape (e.g. Pathfinder, iTree, Vectorworks) this study also poses the question if BIM is the most suitable tool to deal with landscape design after all. Acknowledging the experience BIM has to modelling and materials calculation for buildings, it seems appropriate to suggest expansions on a larger scale. Regarding landscape design and planning, BIM could contribute to ways in which digital tools can support the identification of natural and morphological characteristics of an area while supporting its design. However, when it comes to less tangible elements, sense of place and aesthetics, it is difficult for digital tools such as BIM to provide the character of a place and atmosphere designers want to infuse to their schemes. This paper does not dismiss this possibility, but it recommends further research.

A significant finding is the lack of connection with regards to climate change and environmental challenges. Despite the broad interest on the climate crisis, there is minimal evidence that BIM has integrated such concepts within its scope. Climate-related features are also relevant to buildings, but they are fundamental elements for future landscape design. The lack of such evidence asks for further research into this topic and the possible challenges that might occur when a digital tool try to calculate environmental characteristics or create models for future challenges. The diagram below (see figure 8) shows the association between landscape areas. This association was identified through cross-checking research papers that identified multiple landscape areas (Climate change, Planning and Urban Design). The usefulness of identifying this association between landscape areas is to highlight the interrelationships between different landscape areas, and more importantly, inform future research on BIM for landscape. Furthermore, this will provide richer insights on BIM for landscape, and how the impact of BIM can be extended from a landscape area to another. Through cross-checking, it was identified that planning was the most area associated with the other landscape areas. While planning is present in both areas, 'planning and climate change' has almost half the significance in comparison to 'planning and urban design'. The diagram reveals the connection between the areas, but it does not demonstrate the severe interaction required to address design and climate challenges into future landscape projects. While evidence created by the literature analysis shown only a small connection between the landscape areas (touching on one side), the reality is that to achieve efficient landscape designs urban design, planning and climate change need to be integrated in the broader vision of the landscape scheme. This suggests that the papers we identified have not examined these concepts with a holistic approach, but as isolated areas, justifying the finding that only two papers have tackled all three landscape areas during their research.

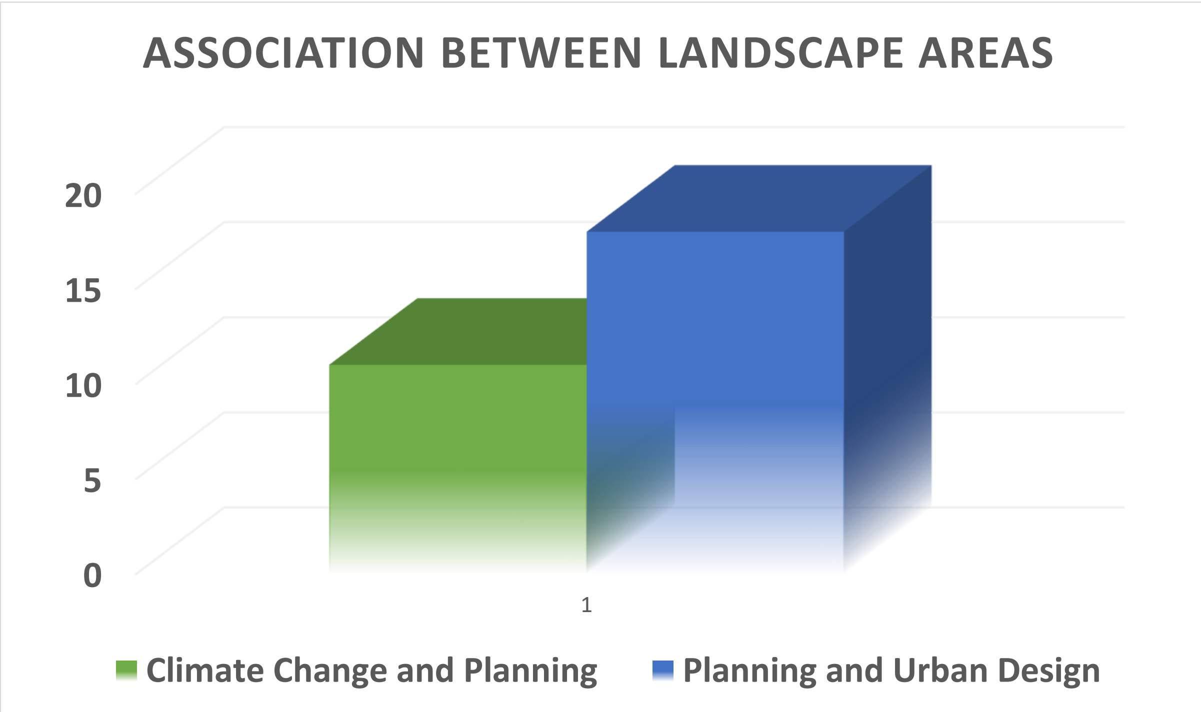

Figure 8: Diagram showing the correlation between the landscape areas as it was identified during the data analysis.

5.2. BIM for Landscape: Reaching a Wider Impact

Based on the previous section, and following the analysis, it can be stated that BIM for landscape would require further development, and in fact, a more proactive approach to achieve wider impact both at research and industry levels. Amongst the three landscape areas within this systematic review, it is recognised that 'planning' can be seen as the moving vehicle where BIM can be applied to create wider impact within landscape, and perhaps extend the impact to other landscape areas such as 'climate change' and 'urban design'. This may be reasoned by the fact that planning includes dimensions that heavily rely on data that can be integrated in BIM Models (e.g. building methods would require specifying material choice, properties and other data), hence the connection can tangibly be more recognised, and the value towards landscape can be mapped.

Based on analysis derived from the Systematic Literature Review (SLR), and interpretation of link between BIM and different dimensions within the three landscape areas in this research, the research suggests several interlinks process between the three landscape areas. These links are based on findings from the SLR, and logical interlink between dimensions within each of the three landscape areas. There are two types of links: strong links (solid arrows), which are based on multiple (more than 3) studies where these links where demonstrated, and weak links (dotted arrows) where links were illustrated based on few (less than 3) studies. The authors indicated BIM and other associated tools that support interlinking with other dimensions on most of the links. BIM-GIS, which combines BIM data and Geographic/geospatial information.

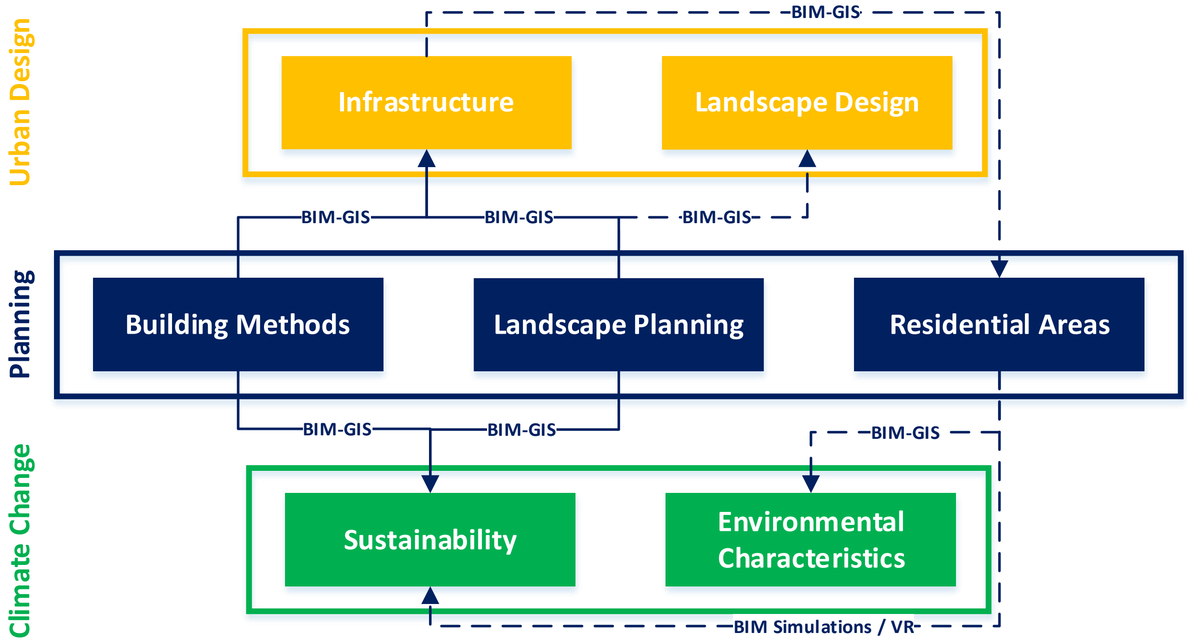

Figure 9: Recommended interlinks between different landscape areas and BIM applications based on analysis derived from the Systematic Literature Review.

From a BIM perspective, it can be stated that planning can be recognised as the main gate where BIM data and visualisations can inform building methods and can support landscape planning. Combining BIM-GIS tools can support informing the infrastructure (Andrianesi and Dimopoulou, 2020; Kuster et al., 2020; Amoruso and Manti, 2016) using data from landscape planning and building methods. Simultaneously, landscape planning can potentially support landscape design, but this requires further investigation as current studies that illustrate are considerably limited. Although "residential areas" is seen as one of the dimensions within planning, from a BIM perspective, it often is impacted by infrastructure. This is especially the case when looking at studies where residential developments is the focus (e.g. Yang et al., 2017; Fujiwara et al. 2015), and infrastructure-related data is used to inform the area where the development will be taking place, but this would also require further exploration. As one of the core landscape areas, climate change may be perceived as the most remotely related area to BIM, and based on very few studies, BIM-GIS and BIM visualisations were seen as one of the potential links where residential areas can support analysing environmental characteristics as well as sustainability. However, from a landscape perspective, it is anticipated that analysis from climate change related dimensions, especially sustainability, would inform both urban design as well as planning. This will support an improved understanding of the wider impact of technologies and advanced processes such as BIM to inform landscape related areas, and more importantly, maintain digital records that inform similar contexts on the long term.

6. CONCLUSION

To sum up, this paper has explored the value of BIM for landscape by using systematic literature review (SLR) as a method in order to interlink tangible connections and future opportunities between BIM and landscape. It can be stated that the interest in future resilience for our urban centres and regions is constantly increasing and the effects of climate change are affecting our landscapes, cities and way of life. It is essential to acknowledge that a holistic approach or vision is necessary to plan at a strategic scale and the emphasis of this paper is given in the ways in which digital tools such as BIM can support such a significant requirement. The paper has revealed that only specific connections between BIM and landscape have been made to date, and this was evidenced through focusing on three main areas within landscape: planning, urban design and climate change. The paper provides a lot of alerting points on the lack of interaction between BIM and the landscape, missing an opportunity for such a digital tool to support landscape professionals. While expanding on the distinctions of BIM and reviews the pace of technological advancements in relation to buildings and open spaces, it is evident that majority of research efforts have focused on the planning side when compared to urban design and climate change. However, with progression in recent years, there is a growing interest in topics related to urban design, but these studies do not provide significant evidence of a broader interest in relation to BIM and landscape, hence requires further investigation.

A key finding has been the isolation of the climate change related dimensions from the scope of BIM, raising concerns about the support such a tool can give to future landscape schemes. It is almost intriguing to fail to address or even touch upon climate crisis-related topics, especially when the goals of COP26 agreed in November 2021 ask for immediate action from decision makers, professionals and the public. The study argues that BIM and digitalisation transformation tools can support landscape by providing accurate data, improving the understanding of the landscape and visualising climate challenges as well as environmental solutions. Sustainable cities need holistic visions to address the climate crisis, but digital tools can potentially provide significant support with visualisation and carbon calculation to enhance these outcomes. This study recommends that future research is required in relation to BIM and the landscape with more emphasis on data and how it interlinks between different landscape areas. Inevitably, an integrated approach needs to be created focusing on how BIM can integrate landscape characteristics and how climate change elements (e.g. temperature, air quality, green space and more) can be embedded in digital tools. It is also pointed that further investigation on the role decision makers, stakeholders and professionals play on the digital transformation of landscape design and planning is required.

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