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Advancements in Building Deconstruction: Examining the Role of Drone Technology and Building Information Modelling

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ABSTRACT

Deconstructing a building with the help of drones and BIM (building information modelling) is becoming increasingly common as a more efficient, eco-friendly, and affordable alternative to the traditional techniques of building disassembly. This paper presents a systematic review following the methodology of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to investigate the role of drone technology and BIM in building deconstruction. A total of 10 studies were identified based on the integration of drone technology with BIM, all of which proved promising in enhancing the process of building deconstruction. The analysis of the 35 and 3 non-academic selected data reveals several key findings. Firstly, BIM is not commonly used in deconstruction or demolition processes, particularly in managing fixtures and fittings of buildings. Secondly, the adoption of deconstruction-oriented design methods and the use of drone technology can significantly reduce the negative environmental impacts of building demolition waste. Lastly, the limited implementation of design for deconstruction practices in the construction industry hinders the realisation of environmental, social, and economic benefits associated with this approach. Overall, this systematic review highlights the potential of drone technology and BIM in improving building deconstruction practices, while also identifying knowledge gaps and areas for further research and development on this topic.

1. Introduction

Building deconstruction has emerged as a sustainable, eco-friendly, and cost-effective alternative to traditional demolitions (Besné et al., 2021; Pratisto et al., 2022). Proper deconstruction practices ensure the selective dismantlement of building components and materials that can be reused, repurposed, or recycled (Besné et al., 2021; Mustaffa & Sailin, 2022). This process helps optimise resource utilisation and reduces the environmental impact of the construction industry (Ali et al., 2022; Besné et al., 2021; Lyu et al., 2022). The

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utilization of deconstruction can minimize solid waste, increase the useful life of materials, preserve embodied energy, and reduce landfills and consumption of natural resources (Spadotto et al., 2022). Deconstruction is a sustainable alternative to demolition and contributes to optimal resource utilization and minimises the environmental footprint of the construction industry. Despite the benefits of building deconstruction, its implementation has been limited by technical and feasibility challenges (Ali et al., 2022). Several technical challenges, such as the need for qualified labour, flexible equipment, and customized approaches were identified by (Obi et al., 2021). One promising approach for addressing these challenges is the use of robots to assist in deconstruction. However, the integration of robots into the deconstruction process requires the development of a framework encompassing various sub-systems such as perception, planning, and control. (Lee et al., 2015) proposes such a framework, which could enable the systematic implementation of robot-assisted deconstruction. Additionally, deconstruction is labour-intensive and can be time-consuming and uneconomical, especially for light wood-framed buildings (Guy, 2006). However, recent advancements in drone technology and building information modelling (BIM) have demonstrated great potential in addressing some of the challenges and improving the efficiency of the deconstruction process (Gohari et al., 2022). The integration of drone technology and Building Information Modelling (BIM) results in superior efficiency and outperforms traditional deconstruction techniques in salvaging materials and minimizing waste (Ge et al., 2017). Drones have also found a place in the construction industry, with the use of aerial, terrestrial, and underground drones in different construction activities, including deconstruction (Szóstak et al., 2022). A term that can be referred to as Drone-BIM deconstruction - a modern approach to building deconstruction and waste management that utilizes technology to provide a faster, cheaper, and environmentally friendly deconstruction method. By combining drone technology and BIM, construction professionals can create 3D models of existing buildings for deconstruction planning, reducing errors and increasing accuracy (Ge et al., 2017). Drones can offer real time information on the state of buildings and infrastructure, enabling more accurate deconstruction and enhanced site monitoring (Musonda & Pillay, 2019; Zabidi et al., 2022).

The construction industry has a knowledge gap regarding the adoption of modern equipment technologies, such as drones, due to insufficient research (Ali Alheeti et al., 2022; Sepasgozar et al., 2018). While there has been significant research on the adoption of information technology in construction, the adoption of modern equipment technologies has been neglected. This gap in knowledge is important because understanding the adoption process of these technologies can help improve their implementation in the construction industry.

Therefore, this systematic review aims to examine advancements in building deconstruction by analysing the role of drone technology and building information modelling.

2. Methodology

This study followed the PRISMA guideline for conducting a comprehensive systematic review (Watson et al., 2023). By following the PRISMA guidelines, authors can provide a transparent and accurate account of the review process, which enhances the credibility, reproducibility, and reliability of the findings (Priyan et al., 2023; Rethlefsen et al., 2021; Scherz et al., 2022). In the context of building deconstruction, a systematic review using PRISMA can help identify and analyse the existing literature on the role of drone technology and building information modelling (BIM) in the deconstruction process. It can provide a comprehensive overview of the current state of knowledge, identify research gaps, and highlight areas for further investigation.

A search was conducted on relevant academic databases including Google Scholar, Science Direct, and Scopus, with keywords such as "building deconstruction", "drone technology," and "BIM." Using the inclusion and exclusion criteria, 35 academic and 3 non-academic sources were selected for data extraction and analysis. Data was synthesized using qualitative and quantitative methods with results and discussions presented.

2.1. Eligibility Criteria

The following are the inclusion and exclusion criteria for the study.

Inclusion criteria:

- Studies on advancements in building deconstruction that involve the use of drone technology and BIM as this is the focus of the research.
- Studies published in English as including studies published in non-English languages may pose resource challenges, such as costs and difficulty in locating and assessing relevant non-English studies (Neimann Rasmussen & Montgomery, 2018).
- Studies published within the last decade as the first mention of Building Information Modelling (BIM) for deconstruction can be traced back to a paper titled "Building Information Modelling for Sustainable Building Deconstruction: A Case Study" by Mahmoud Al-Derbi et al. in 2014. This paper highlights the potential benefits of using BIM in the process of deconstructing buildings, such as improved planning, increased efficiency, and enhanced sustainability.
- Studies that involve peer-reviewed journal articles as peer review ensures the quality and credibility of published articles, prevents bias, and provides a level of accountability to the research community (Halder et al., 2021; Stichler, 2017)

Exclusion criteria:

- Studies that do not focus on the use of drone technology and BIM in building deconstruction.
- Studies not published in English and focused on other topics that are not related to building deconstruction.
- Studies with no abstract available and are not peer-reviewed journal articles.

A summary of eligibility criteria used is presented in Table 1 below:

Table 1.
Summary of eligibility criteria

Eligibility Criteria	
Inclusion	**Exclusion**
Drone and BIM-based building deconstruction research emphasis.	Non-drone and BIM-related building deconstruction studies.
Research published in English	Studies not published in English
Studies published within the last decade (2013 – June 2023)	Studies covered non-building deconstruction subjects.
peer-reviewed journal articles	Studies with no abstract available non-peer-reviewed journal articles.

The results of the search and progression of screening for the research question are displayed in Figure 1.

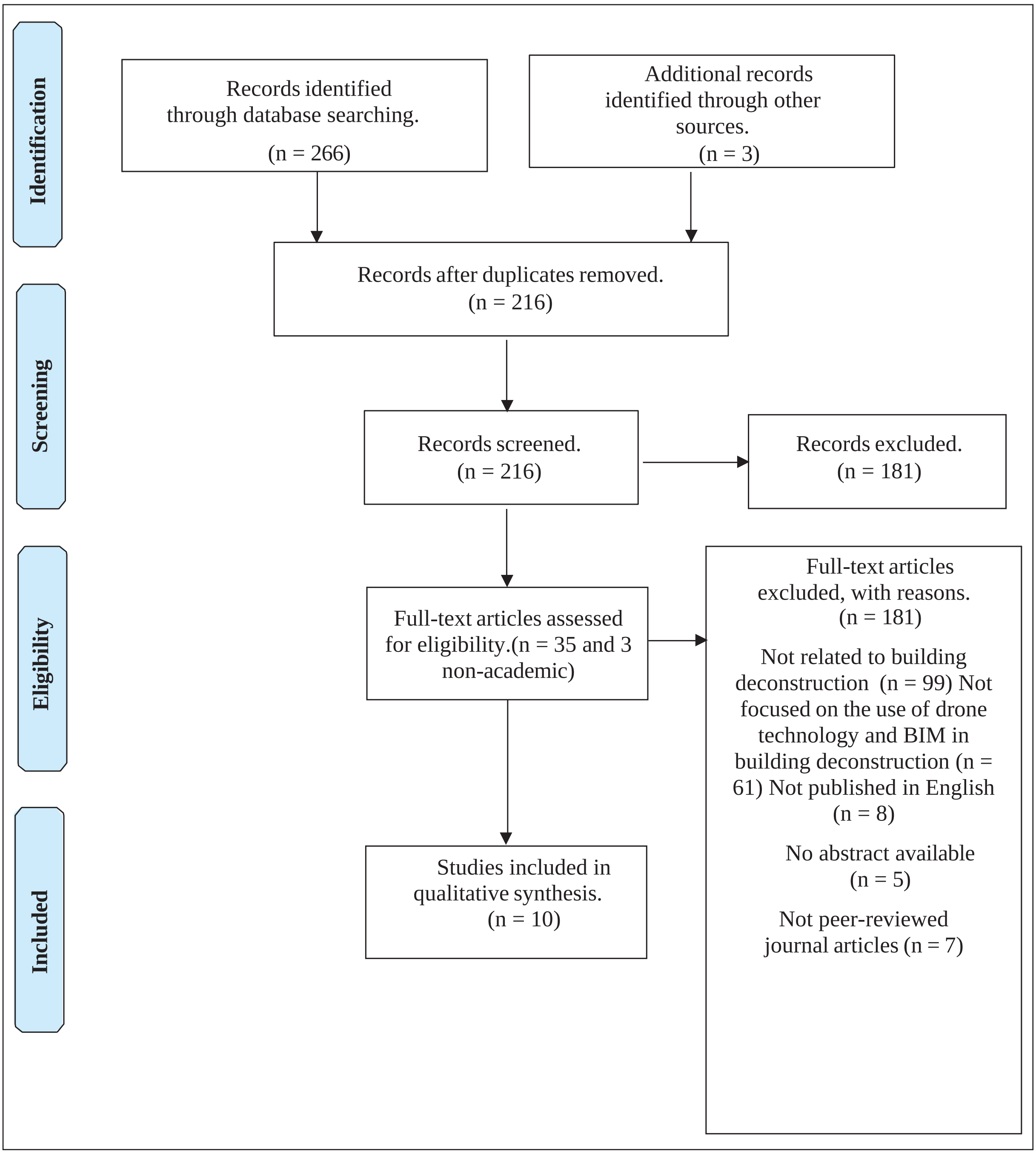

Figure 1. PRISMA flow diagram of review search for research question (Adapted from https://libguides.mq.edu.au/systematic_reviews/prisma_screen)

3. Results

The review revealed that deconstruction waste management is a vital part of the construction industry's circular economy strategy (Besné et al., 2021; Lyu et al., 2022). Several studies have highlighted the potential of drone technology and BIM in the deconstruction process. (Lee et al., 2015) proposed a framework for robot-assisted deconstruction using a combination of drones and BIM. The use of drones in building inspections before the actual deconstruction begins can improve the planning and execution of the process (Lyu et al., 2022). Marzouk and Elmaraghy investigated the use of BIM in deconstruction planning, leading to a proposed tool to reduce uncertainties involved in demolition projects (Gohari et al., 2022).

The review also highlighted the need to consider the environmental impacts of the deconstruction process, such as noise, dust, and vibrations (Goldsmith et al., 2007). This highlights the importance of incorporating environmental impact assessments, which can guide the selection of appropriate deconstruction methods (Ali et al., 2022). Additionally, the review found that design for deconstruction during the design process could improve the sustainability of the building's life cycle (Pratisto et al., 2022).

Keyvanfar & Shafaghat (2022), investigated the utilisation of UAVs in architecture and construction management projects throughout all stages. Their research identified nine (9) dimensions of UAV' 3D modelling capabilities in the Architecture Engineering and construction industry; D1. Quality management, D2. Risk Management, D3. Site monitoring, D4. Project performance and progress control, D5. Facilities Management, D6. Building Measurement, D7. On-Site Information Analysis, D8. Team Collaboration and communication, and D9. Workers Training. The research found that building measurement and quality management are the most rapidly growing dimensions. However, through a critical review of the understudied research works, all the dimensions identified were within the RIBA 7-stage plan of work without any attention to the end-of-life phase. Table 2 below adapted from (Keyvanfar & Shafaghat, 2022) incorporates a 10th dimension D10 which is UAV's 3D modelling for deconstruction accounting for the end-of-life phase of the building.

Table 2.
Unmanned Aerial Vehicle 3D Reconstruction Modelling Applications in Architecture and Civil Engineering

Citation	**D1. Quality Management**					**D2. Risk Management**			**D3. Site monitoring**			**D4. Project performance control**				**D5. Facilities Management**					**D6. Building Measurement**						**D7. On-Site Information Analysis**				**D8. Team Collaboration**			**D9. Workers Training**			**D10. Deconstruction**		
	D1.1.Using AR system	D1.2.Using BIM	D1.3.Integrating AR and BIM	D1.4.Integrating AR, BIM, and image-matching system	D1.5.Using inspection tools	D2.1.Risk of accidents	D2.2.Risk of hazardous situations	D2.3.Safety for laborers and workers	D3.1.Using a WLAN-based AR system	D3.2.Using image stitching technique	D3.3.Using web-based VR	D4.1.Using AR for virtual scheduling	D4.2.Using an AR-based 4D CAD system	ID4.3.ntegrating location-based management system	D4.4.Image-based 3D & 4D reconstruction	D5.1.Using BIM	D5.2.Using VR technology	D5.3.Using integrated AR and BIM	D5.3.Using BIM2MAR	D5.4.Using Game engine technologies	D6.1.Image-based 3D reconstruction and meshing	D6.2.Geo-referencing and using GPS data	D6.3.3D mapping	D6.4.using RGB sensors and 3D rotating laser scanners	D6.5.Image segmentation and Orthophoto mapping	D6.5.Using AR for digital fabrication	D7.1.Using wearable device	D7.2.Using HD4AR system	D7.3.Using AR system	D7.4.Integrating BIM and AR system	D8.1.Integrating game technology with web-based VR	D8.2.Applying MR technologies	D8.3.Integrating BIM and VR systems	D9.1.Applying VR-based training simulators	D9..2.Using 360 VR system	D9.3.Integrating VR and MR	D10. UAV' s 3D modelling for deconstruction	D10. UAV' s 3D modelling + BIM for deconstruction planning	D10. UAV' s 3D modelling + BIM for post deconstruction material reuse
Goulding et al., (2012)																					'										'			'					
Sampaio et al., (2012)	'				'											'										'													
Yeh et al., (2012)			'										'														'			'									
Xie et al., (2018)					'			'		'	'										'								'										

Citation	**D1. Quality Management**					**D2. Risk Management**			**D3. Site monitoring**			**D4. Project performance control**				**D5. Facilities Management**					**D6. Building Measurement**						**D7. On-Site Information Analysis**				**D8. Team Collaboration**			**D9. Workers Training**			**D10. Deconstruction**		
	D1.1.Using AR system	D1.2.Using BIM	D1.3.Integrating AR and BIM	D1.4.Integrating AR. BIM. and image-matching system	D1.5.Using inspection tools	D2.1.Risk of accidents	D2.2.Risk of hazardous situations	D2.3.Safety for laborers and workers	D3.1.Using a WLAN-based AR system	D3.2.Using image stitching technique	D3.3.Using web-based VR	D4.1.Using AR for virtual scheduling	D4.2.Using an AR-based 4D CAD system	ID4.3.ntegrating location-based management system	D4.4.Image-based 3D & 4D reconstruction	D5.1.Using BIM	D5.2.Using VR technology	D5.3.Using integrated AR and BIM	D5.3.Using BIM2MAR	D5.4.Using Game engine technologies	D6.1.Image-based 3D reconstruction and meshing	D6.2.Geo-referencing and using GPS data	D6.3.3D mapping	D6.4.using RGB sensors and 3D rotating laser scanners	D6.5.Image segmentation and Orthophoto mapping	D6.5.Using AR for digital fabrication	D7.1.Using wearable device	D7.2.Using HD4AR system	D7.3.Using AR system	D7.4.Integrating BIM and AR system	D8.1.Integrating game technology with web-based VR	D8.2.Applying MR technologies	D8.3.Integrating BIM and VR systems	D9.1.Applying VR-based training simulators	D9..2.Using 360 VR system	D9.3.Integrating VR and MR	D10. UAV' s 3D modelling for deconstruction	D10. UAV' s 3D modelling + BIM for deconstruction planning	D10. UAV' s 3D modelling + BIM for post deconstruction material reuse
Sacks et al., (2013)					'	'	'																												'					
Park & Kim, (2013)								'				'								'											'	'	'	'					
Kwon et al., (2014)				'						'	'	'		'															'	'									
Zollmann et al.(2014)															'								'						'										
Siebert & Teizer, (2014)										'											'	'	'	'					'										
Hou et al., (2013)	'								'		'		'				'												'						'	'	'		
Williams et al., (2014)																		'	'											'									
D. Kim et al., (2019)											'	'	'		'														'				'						
Zhao & Lucas, (2014)						'	'																											'					
White et al., (n.d.)													'		'																'	'	'				'		
Irizarry & (Costa, 2016)	'				'			'				'									'									'									
Pedro et al. (2016)					'			'															'	'										'					
Zhou et al., (2015)																					'				'														
Bang et al., (2017)										'	'				'														'							'			
H. Kim et al., (2017)					'		'	'																				'											

Citation	D1. Quality Management					D2. Risk Management			D3. Site monitoring			D4. Project performance control				D5. Facilities Management			
	D1.1.Using AR system	D1.2.Using BIM	D1.3.Integrating AR and BIM	D1.4.Integrating AR, BIM, and image-matching system	D1.5.Using inspection tools	D2.1.Risk of accidents	D2.2.Risk of hazardous situations	D2.3.Safety for laborers and workers	D3.1.Using a WLAN-based AR system	D3.2.Using image stitching technique	D3.3.Using web-based VR	D4.1.Using AR for virtual scheduling	D4.2.Using an AR-based 4D CAD system	ID4.3.ntegrating location-based management system	D4.4.Image-based 3D & 4D reconstruction	D5.1.Using BIM	D5.2.Using VR technology	D5.3.Using integrated AR and BIM	D5.3.Using BIM2MAR	D5.4.Using Game engine technologies
Chu et al. (2018)			'				'			'	'			'						
Fazel and Izadi (2018)	'										'						'			
Kim and Kim (2018)										'	'									
Chalhoub and Ayer (2018)											'									
Du et al. (2018)	'				'						'									
Portalés et al. (2018)					'															
Cao et al., (2022)								'		'	'									
van den Berg et al., (2021)					'		'	'												
Gordon et al., (2023)	'		'		'									'						

Citation	D6. Building Measurement						D7. On-Site Information Analysis				D8. Team Collaboration			D9. Workers Training			D10. Deconstruction		
	D6.1.Image-based 3D reconstruction and meshing	D6.2.Geo-referencing and using GPS data	D6.3.3D mapping	D6.4.using RGB sensors and 3D rotating laser scanners	D6.5.Image segmentation and Orthophoto mapping	D6.5.Using AR for digital fabrication	D7.1.Using wearable device	D7.2.Using HD4AR system	D7.3.Using AR system	D7.4.Integrating BIM and AR system	D8.1.Integrating game technology with web-based VR	D8.2.Applying MR technologies	D8.3.Integrating BIM and VR systems	D9.1.Applying VR-based training simulators	D9..2.Using 360 VR system	D9.3.Integrating VR and MR	D10. UAV' s 3D modelling for deconstruction	D10. UAV' s 3D modelling + BIM for deconstruction planning	D10. UAV' s 3D modelling + BIM for post deconstruction material reuse
Chu et al. (2018)									'	'			'			'	'		'
Fazel and Izadi (2018)						'			'		'								
Kim and Kim (2018)									'										
Chalhoub and Ayer (2018)										'		'					'	'	
Du et al. (2018)	'										'	'							
Portalés et al. (2018)	'		'			'									'				
Cao et al., (2022)	'			'		'											'		'
van den Berg et al., (2021)								'							'				
Gordon et al., (2023)	'	'	'								'	'	'				'	'	

Source: Authors

Three thematic areas were discovered from the qualitative analysis of the selected articles which includes (i) BIM for Deconstruction, (ii) Deconstruction Oriented Design method and Drone Technology and (iii) Benefits of Integrated drone technology and Building Information modelling in Deconstruction planning and implementation. These are discussed in the following sections below.

3.1. BIM for Deconstruction

Governments worldwide create laws and regulations to promote recycling and reusing of building materials, with the goal of minimising waste and environmental harm. Scholars are devising waste management strategies and frameworks for the construction and demolition of structures. BIM exemplifies this. BIM is a technology that is commonly utilised to optimise the efficiency of design, construction, and maintenance over the entire lifecycle (Ge et al., 2017). The development of BIM is based on two-dimensional drawings or sketches, which may not be accurately converted to 3D BIM models. Also, according to (Gankhuyag & Han, 2020), the lack of accurate building drawings and documentation, along with undocumented alterations made during renovation or refurbishment over time, poses challenges in planning the deconstruction process effectively.

Ge et al., (2017)'s case study on deconstruction waste management found that the use of BIM in managing fixtures and fittings of buildings is not commonly practiced. The authors highlight the need for incorporating these elements within BIM models.

Wu, (2017) discusses the limited use of BIM in the demolition or reconstruction phase, specifically in minimizing and managing demolition waste. The author emphasizes that although BIM has been extensively applied in design and construction stages, its application in deconstruction is still limited.

Van den Berg et al., (2021), state that demolition contractors rarely implement BIM due to challenges associated with high modelling efforts, updating information in models, and handling uncertain data. The article highlights the additional difficulties that discourage the widespread use of BIM in deconstruction practices.

Freitas et al., (2021), conducted a review of literature on the application of BIM in construction and demolition waste management. The study found that the use of BIM in deconstruction practices is limited, indicating the underutilization of BIM in this field highlighting the need for an as-built model for BIM to identify and measure recyclable materials.

In summary, various studies (Freitas et al., 2021; Matarneh et al., 2017; van den Berg et al., 2021; Wu, 2017) indicate that BIM is not commonly utilized in deconstruction or demolition processes, particularly in managing fixtures and fittings of buildings.

Summarily, challenges associated with high modelling efforts, updating information, and handling uncertain data in addition to lack of accurate building drawings and documentation, along with undocumented alterations made during renovation or refurbishment over time represents factors for underutilisation of BIM in deconstruction practices. The limited use of BIM in the demolition phase and the challenges associated with its implementation contribute to the underutilization of this technology in deconstruction practices.

3.2. Deconstruction Oriented Design Method and Drone Technology

Deconstruction-oriented design methods and the use of drone technology have emerged as promising approaches to reduce the negative environmental impacts of building demolition and deconstruction processes. These innovative practices have gained attention among architects, engineers, and researchers who are focused on promoting sustainability and the circular economy in the construction industry (Bertino et al., 2021). By adopting deconstruction-oriented design methods and incorporating drone technology, significant strides can be made towards minimizing waste generation, maximizing material reuse, and improving the overall efficiency of the demolition and deconstruction processes.

One important aspect in the adoption of deconstruction-oriented design methods is the consideration of its environmental impact. A study by (Ding et al., 2016) revealed that widespread adoption of deconstruction-oriented design methods can reduce the negative environmental impacts of building demolition waste by at least 50%. This highlights the potential of designing buildings with deconstruction in mind, considering factors such as material separability and ease of disassembly. By incorporating these considerations into the design phase, the eventual deconstruction and material recovery processes can be more efficient and environmentally friendly.

In addition to design considerations, the use of drone technology has shown promise in improving the efficiency and effectiveness of building demolition and deconstruction. Drones equipped with high-resolution cameras and sensors can provide detailed visual information about the building, aiding in the planning and assessment stages (Jakovljević, 2021). For instance, drones can be utilized to create accurate 3D models of the building, allowing for precise measurements and visualizations of the structure. This enables engineers and contractors to better plan the deconstruction process, optimize material recovery, and reduce potential hazards.

The implementation of deconstruction-oriented design methods and the use of drone technology are crucial for achieving sustainable development goals, particularly in developing countries (NSUDE & Ifeyinwa, 2020). The challenges faced by these countries, such as poverty and inadequate infrastructure, can be addressed through the application of innovative technologies like drone technology. Drones have the potential to provide valuable insights, facilitate data collection, and improve efficiency in the building demolition and deconstruction processes (NSUDE & Ifeyinwa, 2020).

Collaboration among professionals from diverse fields is crucial for maximising the advantages of deconstruction-oriented design techniques and drone technology. Collaboration among architects, engineers, contractors, and waste management experts is necessary to incorporate these practises into the conventional construction industry. Policymakers and regulatory bodies should promote and incentivize sustainable practises in demolition and deconstruction. This includes using deconstruction-oriented design methods and drone technology.

In summary, employing deconstruction-oriented design techniques and utilising drone technology offer potential solutions for mitigating the adverse ecological effects of building demolition and deconstruction. These practises enhance the circular economy by reducing waste, optimising material reuse, and increasing efficiency. Despite existing challenges such as limited BIM integration and technological barriers, advancements in these areas have the potential to revolutionise the construction industry, promoting sustainable development and resource conservation.

3.3. Benefits of Integrated Drone Technology and Building Information Modelling in Deconstruction Planning and Implementation

While the laser scanner has been the leading method for Scan-to-BIM procedure, shortcomings exist, and drones provide alternatives to enhance the process significantly (Irizarry et al., 2023). Combining drones with other automated technologies for deconstruction optimizes efficiency and effectiveness, surpass conventional techniques (Lee et al., 2015).

This review of literature provides insight into the factors that influence successful implementation of BIM for deconstruction.

3.3.1. Enhanced Planning and Visualization

Drones offer exceptional visual data that facilitates precise 3D mapping of structures prior to deconstruction (Ge et al., 2017), enhancing planning and visualisation. By capturing high-resolution images and videos, drones offer a comprehensive record of the building's condition, facilitating precise and informed decision-making during the planning phase. Combining this data with BIM models allows for a detailed understanding of the structure's components and their interrelationships (McCuen, 2015). This integration enhances the visualization of the deconstruction process, aiding in identifying potential challenges and optimizing the sequencing of tasks.

3.3.2. Improved Safety and Efficiency

In the building and demolition industries, safety is of the utmost importance. Drones equipped with advanced imaging technologies can conduct inspections of deteriorated or inaccessible areas, mitigating the need to send workers into hazardous environments (Hoeft & Trask, 2022). This reduces occupational safety risks, enhancing worker well-being. Additionally, drones can monitor the site in real-time, identifying potential hazards and ensuring compliance with safety regulations. In addition, digital simulations and virtual walkthroughs are made possible by combining BIM models with data collected by drones, which aids in the early detection of potential collisions or conflicts during demolition (Hoeft & Trask, 2022). The efficiency gains and cost savings from fixing these problems early on are substantial.

3.3.3. Accurate Quantification and Inventory Management

Precise assessment of salvaged materials and effective inventory management are critical in deconstruction processes. Drones equipped with sensors and cameras enable accurate material quantification, aiding in the assessment of recoverable components and potential reusability (Rufino et al., 2023). Accurate quantification facilitates waste diversion optimization and environmental impact minimization. BIM integration facilitates real-time material tracking and efficient inventory management during deconstruction (Hoeft & Trask, 2022). This facilitates the efficient identification, removal, and repurposing of salvaged materials.

3.3.4. Enhanced Sustainability and Circular Economy

The integration of drone technology and BIM in deconstruction enhances sustainability and supports the circular economy. Drones capture extensive data that assists in identifying salvageable materials, reducing the need for virgin resources (Ge et al., 2017). The integration of BIM models with drone-collected data enables efficient planning and execution of material reuse, minimising waste generation and reducing the environmental impact of deconstruction projects through optimised material recovery. This approach is in line with the worldwide effort to promote a sustainable and circular construction sector.

3.4. Limitations of Integrated Drone Technology and BIM in Deconstruction Practices

Drones have revolutionized data collection, while BIM provides a virtual representation of the physical environment. When combined, they offer great potential in enhancing deconstruction practices. However, like any technology, integrated drone technology and BIM have their limitations, which must be acknowledged and addressed to fully harness their benefits.

Data Accuracy and Quality:

The accuracy and quality of data collected by drones can be affected by environmental factors such as wind, precipitation, and poor lighting conditions. Inaccurate data can lead to errors in the BIM model, which can result in costly mistakes during deconstruction.

For instance, a study conducted by Ismail and Tomar (2018) found that drone-based data collection accuracy decreased significantly in adverse weather conditions, emphasizing the need for supplementary data sources.

Data Processing and Integration:

The integration of drone-captured data with BIM models requires extensive data processing and analysis. This process can be time-consuming, especially for large-scale projects. Additionally, the accuracy of the integration heavily relies on the quality of the software and the expertise of the operators.

Research by Zhu et al. (2017) highlights the challenges of integrating drone-captured data with BIM and emphasizes the need for improved software and data processing workflows.

Regulatory Hurdles:

The use of drones for data collection is subject to strict regulations and legal constraints, which can vary from one jurisdiction to another. Obtaining necessary permits and adhering to safety regulations can be a cumbersome process.

A study by Federal Aviation Administration (FAA) (2020) outlines the complex regulatory landscape for drone operations and the need for ongoing compliance monitoring.

Cost and Resource Constraints:

Implementing integrated drone technology and BIM requires a significant initial investment in hardware, software, training, and maintenance. Smaller construction companies may find it challenging to bear these costs, limiting the widespread adoption of this technology.

Hwang and Wu (2018) argue that the high initial costs are a significant barrier to entry for small to medium-sized construction firms, who may not have the resources to invest in integrated drone and BIM systems.

Privacy and Security Concerns:

The collection of data using drones raises concerns about privacy and data security. Unauthorized access to sensitive project information or images captured by drones can be a significant risk.

Research by Snavely et al. (2018) highlights the importance of implementing robust data security protocols and ensuring privacy compliance in drone-based data collection.

Skills Gap:

The successful implementation of integrated drone technology and BIM in deconstruction practices relies on skilled operators and analysts who can manage both the hardware and software aspects effectively. The construction industry may face a shortage of professionals with the required expertise.

Wang et al. (2020) argue that addressing the skills gap through training and education programs is crucial to ensure the successful adoption of integrated drone technology and BIM in the construction industry.

4. Discussion

The review establishes that building deconstruction is a viable alternative to traditional demolitions and plays a crucial role in the construction industry's circular economy strategy (Besné et al., 2021; Lyu et al., 2022). The use of drone technology and BIM in the deconstruction process can improve planning, execution, and reduce uncertainties involved in the process (Gohari et al., 2022; Li & Liu, 2018). Deconstruction waste management can be optimized by integrating environmental impact assessments in the planning phase, while designing for deconstruction in the design process can improve a building's sustainability (Ali et al., 2022; Goldsmith et al., 2007; Pratisto et al., 2022). (Balogun et al., 2022) developed a construct-based deconstructability framework providing guidance on the conditions under which deconstruction is likely to work, and the drivers influencing deconstructability.

A summary table is presented in Table 3 of key selected articles analysed in this review highlighting author(s), title of research and practical implication of research.

Table 3.
Summary table of Key articles mentioned in review

Authors	**Research title**	**Research Done**
(Sidani et al., 2022)	Bim Approaches For Enhanced Health and Safety Status In Construction - Protocol For A Systematic Review.	proposed a systematic review to investigate current BIM-based technologies, including drone technology, and evaluate their effectiveness and usability in enhancing occupational health and safety status in the architecture, engineering, construction, and operations (AECO) industry.
(Cao et al., 2022)	Green Building Construction: a Systematic Review Of Bim Utilization.	conducted a systematic review of BIM utilization in the construction phase of green buildings using PRISMA protocols to bridge the research gap and review the latest BIM capabilities.
(Cao et al., 2022)	Green Building Construction: a Systematic Review Of Bim Utilization.	performed a systematic literature review to evaluate the BIM capabilities in the operation and maintenance phase of green buildings. They used the PRISMA protocol to achieve this goal.
(Ge et al., 2017)	Deconstruction Waste Management Through 3d Reconstruction and Bim: A Case Study.	discussed the application of BIM in deconstruction waste management, specifically using 3D reconstruction and BIM in a case study. The article highlighted that the use of BIM in deconstruction or demolition processes is not common, and the fixtures and fittings of buildings are not considered in BIM models.
(Akbarieh et al., 2020)	Bim-based End-of-lifecycle Decision Making and Digital Deconstruction: Literature Review.	reviewed the literature on BIM-based end-of-lifecycle decision-making and digital deconstruction to minimize construction and demolition waste (CDW). The article identified several research directions concerning the BIM-based EoL domain, including BIM-based deconstruction, BIM aided waste management, and BIM-based Design for Deconstruction (DfD).
(Besné et al., 2021)	A Systematic Review of Current Strategies and Methods for BIM Implementation in the Academic Field	analysed which methods are being used by higher education institutions around the world to integrate BIM implementation in AEC (architecture, engineering, and construction) and to determine if a set of regulatory guidelines exists that could serve as a common foundation for institutions to improve this integration process.

Authors	Research title	Research Done
(van den Berg et al., 2021)	A Systematic Review of Bim Requirements Throughout a Whole Life Cycle Of A Project.	explored how deconstruction practices can be reorganised with BIM by applying an activity-theoretical perspective to a nursing home. Three new BIM uses for deconstruction: “3D existing conditions analysis,” “reusable elements labelling” and “4D deconstruction simulation” were proposed.
(Bertino et al., 2021)	Fundamentals of Building Deconstruction as a Circular Economy Strategy for the Reuse of Construction Materials.	Identified reduction of building complexity, smart choice of the materials to be used for the construction, access to the information regarding building construction and deconstruction, and defining a deconstruction methodology for the whole planning process to include deconstruction principles at every lifecycle stage as key points towards building deconstruction adoption.
(Mahajan, 2021)	Applications Of Drone Technology in Construction Industry: a Study	conducted a study that discussed drone technology's application in the construction industry from 2012 to 2021, including its opportunities, challenges, limitations, and strategies for adoption in construction activities. The study helps building planners, contractors, academicians, engineers, architects to improve construction activities' efficiency and performance.
(Balogun et al., 2022)	Systematic review of drivers influencing building deconstructability: Towards a construct-based conceptual framework	developed a construct-based deconstructability framework providing guidance on the conditions under which deconstruction is likely to work, and the drivers influencing deconstructability.

Source: Authors

A common denominator for the articles analysed in Table 3 above is their emphasis on the need for new and improved methods and innovative services that could lead to a net reduction in the use of resources and minimizing the waste disposed of in landfills. The three dimensions of BIM application for deconstruction identified through the synthesis of these literatures informed the decision for the three subcategories under D10- Deconstruction in Table 2 above.

5. Conclusion

Building deconstruction offers a sustainable, eco-friendly, and cost-effective alternative to traditional demolitions. The incorporation of recent advancements such as drone technology and BIM can improve the efficiency of the deconstruction process. The integration of drone technology and Building Information Modelling offers numerous benefits in the planning and implementation of deconstruction projects. The use of drones enables enhanced planning, visualization, safety, and efficiency, while BIM facilitates accurate quantification, inventory management, and the promotion of sustainability. As the construction industry explores more sustainable practices, the adoption of these technologies can significantly contribute to efficient, environmentally responsible, and circular deconstruction processes.

The literature review highlights the role of BIM and drone technology in building deconstruction. In conclusion, the examination of advancements in building deconstruction by analysing the role of drone technology and building information modelling (BIM) reveals several key findings:

- The adoption of modern equipment technologies in the construction industry falls into three stages, with vendors playing a crucial role in the adoption process.
- The use of autonomous drones equipped with high-speed cameras has emerged as an effective method for detecting cracks in buildings, enhancing safety, and reducing costs.
- Deconstruction-oriented design methods and the use of drone technology have gained attention among architects, engineers, and researchers focused on promoting sustainability and the circular economy in the construction industry.
- The characteristics of buildings and the procedures adopted in the deconstruction process significantly influence the viability of deconstruction and the reutilization of materials and components.
- Multi-objective optimization analysis and selective disassembly planning can enhance the efficiency and efficacy of deconstruction processes.

In summary, advancements in building deconstruction through the utilization of drone technology and BIM offer promising approaches to reduce the negative environmental impacts of demolition and deconstruction processes. However, there are still challenges to overcome, such as limited adoption, high modelling efforts, and the lack of accurate building drawings and documentation. Further research and development are needed to fully harness the potential of these innovative practices and promote sustainability and the circular economy in the construction industry.

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