

TOOLS AND TRENDS IN REAL ESTATE SUSTAINABILITY ASSESSMENT

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ARTICLE INFO	ABSTRACT
<i>Keywords:</i> sustainability, real estate valuation, real estate value, co-currency analysis	The aim of this research was to identify the current trends and tools in the field of real estate sustainability assessment and to determine their relevance for real estate valuation. Bibliometric analysis, an in-depth search of Web of Science sources and a co-occurrence or cluster analysis were used to meet the objective. From the research, it was found that LEED and BREEAM certifications are the most widely used among the current trends and tools in real estate sustainability assessment. Sustainability itself shows relationships with property valuation, but these are not strong, and therefore it can be assumed that, currently, sustainable properties do not have the concept of valuation itself, nor is this topic the main focus of the research. On the positive side, there is potential for sustainability in real estate valuation issues, where sustainability certifications are expected to play an increasingly important role in the real estate valuation process in the future. A limitation of the research is the fact that many publications do not directly address the sustainable property valuation process, but this is a potential for a new research direction that would specifically address the sustainable property valuation process.
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1. Introduction

Sustainability assessment of buildings began to gain importance in the early 2000s and is now increasingly relevant (Lazar & Chithra, 2021). In recent years in particular, sustainability has been a key issue in the construction and real estate industry, with an increasing emphasis on its integration into the property assessment process. The construction industry is one of the most critical sectors of the economy today which is greatly affected by global warming (Michalak & Michalowski, 2021). The architecture, engineering and construction sector has a significant impact on the environment and economy and researchers have identified an important area for intervention as the industry is a major contributor to greenhouse gas emissions (Jamoussi et al., 2022). The current trend of green and sustainable construction is driven by

environmental protection initiatives and the growing demand for better indoor air quality in the real estate market (Apanavičienė et al., 2020).

After decades of human neglect and indifference to resource degradation and environmental degradation, the current conditions for urban life are seriously threatened (Vardopoulos, 2022). As change becomes inevitable in our world, it is important to expand the adaptive capacity of buildings to respond to new variables and changing conditions throughout their life cycle to meet global sustainability requirements (Askar et al., 2021). Life cycle sustainability is increasingly valued in the construction and industrial sectors, which has a significant impact on the environment, economy and society (Dong et al., 2023). The rapid growth of sustainability has resulted in the proliferation of zero energy and energy efficient buildings in all regions of

the world (Manzoor et al., 2022). This increase is due to the importance that researchers, industry, government and society now attach to these issues (Colorado et al., 2020).

Sustainability assessments are becoming an integral part of the property valuation process, which seeks to strike a balance between economic, environmental and social considerations. In recent years, real estate sustainability initiatives have become key factors in addressing environmental, ecological and socio-economic issues (Chrysikopoulos et al., 2024). Considering sustainability in property valuation not only reflects the growing awareness of the environmental impact of operations, but also brings economic and environmental benefits to owners, tenants and society as a whole. In this context, it is crucial to understand the tools and trends in assessing the sustainability of properties and their impact on the valuation of these properties.

Given the growing interest in sustainability within real estate, the aim of the research is to identify current trends and tools in the field of real estate sustainability assessment and to determine their relevance to real estate valuation. In order to fulfill the aim of the thesis, two research questions were set:

Identifying key trends in sustainability assessment and understanding these trends is essential to understanding the current and evolving sustainability of the construction industry. Identifying how these trends translate into property values can provide great insight into how property markets are growing and what the key differences in property values are. This led to the first research question:

RQ1: What are the current main trends in the assessment of the sustainability of real estate and how do these trends affect the real estate valuation process?

It is important to identify the most effective tools and methods for assessing the sustainability of real estate. Knowledge of these tools and methods is important to ensure sustainable assessment and effective use in conjunction with how these tools affect the property valuation process and how they impact on economic, environmental and social conditions. This led to the second research question:

RQ2: What are the most effective tools for assessing property sustainability and how do they relate to property valuation?

2. Literary research

Growing awareness of the environmental impact of our activities and the drive for economic efficiency are

leading to an increasing emphasis on sustainability in the construction and real estate industry. Paying attention to the sustainability of real estate and working towards it is essential to achieving a more sustainable society (Sanei, 2022). This issue has been explored by Zhang et al. (2023) where they used a quantitative analysis of sustainable buildings in terms of their energy efficiency and carbon footprint, and found that the whole system is energy efficient in the operational and material sectors. In contrast, Lai et al. (2022) used logistic regression to find higher adoption rates of sustainability practices in office buildings than in multifamily housing, and in both cases, older buildings that have adopted sustainable practices are more valuable and require less energy than before renovation. Using data mining, Lu et al. (2020) found that decoupling the building sector from carbon emissions through policy, technology and model innovation is an effective way to reduce pollution and achieve the environmental goal. Research by Afzal et al. (2020) critically reviewed the existing research on computational optimization of the RC design of structures for minimum environmental impact to highlight the current status and future trends for advancing building design optimization.

Due to the high impact of greenhouse gases, energy consumption and the quality of life throughout the life cycle of buildings, they have become a topic of great attention nowadays (Mohammed et al., 2023). Therefore, businesses in the building sector have an obligation to contribute to the reduction of carbon emissions. One of the ways to achieve this is by developing the green building concept, which is one of the solutions for sustainable development (Utomo et al., 2022). Green buildings continue to expand in terms of lifestyle throughout the world, but these projects often face greater challenges than traditional projects due to the introduction of new sustainable technologies. This issue is addressed by research by Nguyen & Macchion (2022) who, using exploratory factor analysis, found that the most influential risks are human resource and technical risk in the construction phase, performance risk in the operation phase, human resource risk in the design phase, financial risk, regulatory and complexity risk, and material risk. In terms of the market value of real estate, it is important to understand the tools and trends in real estate sustainability assessment and their relationship to the real estate valuation process. This is confirmed by research by Boarin et al. (2020), who collected and analyzed the views of students and evaluated their

relationship with the educational programs offered by their institutions and found that virtually all participating students considered sustainability to be a key aspect of their education.

With the rapid development of information technology, building information modeling (BIM) is widely applied in the evaluation of green buildings and has attracted much attention. This issue has been investigated in a study by Su and Hong (2022), where a knowledge graph of research methods for green building BIM evaluation was constructed through a quantitative literature review using the Web of Science Core Collection and CiteSpace database. This issue was also investigated by Ali et al. (2022) who investigated the current status and future trends regarding Building Information Modeling (BIM) from the Web of Science database using co-occurrence and co-citation analysis along with network visualization. Practically the same methods are used in the study by Y. Liu et al. (2024), who used the quantitative research technique incorporating VOSviewer and CiteSpace software and the Web of Science Core Collection (WoSCC) database, found that BIM is an important aspect that is necessary to improve the efficiency, sustainability and understanding of buildings and structures, thus creating a relationship where there is an opportunity to improve the planning, construction and management of buildings. In the research, Li et al. (2020) found, through bibliometric method and scientometric analysis, that BIM and multi-objective optimization have recently become the hotspots of research. The bibliometric method was also used in the research of Liang et al. (2021) where they found that, in the development of research efforts in real estate sustainability, the authors of publications initially focused only on the environment and only subsequently considered economic and social impacts. Research by Sandanayake et al. (2020), using a bibliometric evaluation and interviewing a panel of experts, focused on the barriers behind the transition of sustainable concrete products to the industrial market, finding the industry to be constrained in the commercial introduction of materials.

The construction industry is responsible for 40% of the world's carbon emissions, 14% of water consumption and 60% of waste production, and contributes to unsustainable conditions, so critical decisions about stability must be made from the outset of construction. Life Cycle Assessment (LCA) is available (Dalla Mora et al., 2020) and LCA has been the focus of Schneider-Marín & Lang (2020), who carried out a case

study on constructed office buildings where standard LCA calculations were performed with monetary valuation models from the literature, and found that valuation and environmental performance is a useful tool for comparing different building types and design elements that provide efficiency and high value. Ellington et al. (2023) used concepts from real estate valuation and, based on an in-depth search of sources, found that real estate illiquidity predicts out-of-sample real estate returns beyond a number of control variables. A systematic and comprehensive life cycle energy assessment is essential to ensure the viability and sustainability of real estate (Vardopoulos, 2022).

Recently, due to changes over time, there is new interest in LCA, and dynamic LCA (DLCA) is becoming a new form of research (Su et al., 2020). Koranteng et al. (2023) investigated how glazing types and their properties could reduce the cooling load through a simulation application and found that a certain type of glazing could reduce the cooling load by 38% and thus save energy. Computer simulations were also used in the research of Gan et al. (2020) where they examined computer simulation and optimization studies aimed at reducing energy consumption and carbon emissions in the life cycle of buildings and found that life cycle design optimization is related to the design, operation and end-of-life of useful building systems, and that future sustainable development towards a circular economy based on renewable resources is of utmost importance. The Circular Economy (CE) paradigm is gaining global public attention as an attempt to save scarce resources, reduce waste and move away from a linear economy (Oluleye et al., 2022). The new paradigm of a circular economy has also been explored by Norouzi et al. (2021), where bibliometric indicators, network citation and multivariate statistical analysis were obtained using Bibliometrix R and VOSviewer package, and subsequent cooccurrence analysis showed that researchers have paid much attention to sustainability, life cycle assessment, renewable energy, energy efficiency and recycling in the last five years.

Bibliometric analysis and an in-depth search of sources from Web of Science will be used as a method of data collection and analysis for both RQs. Subsequently, VOSviewer software will be used to perform a co-occurrence analysis to determine the impact of trends and tools in real estate sustainability assessment on real estate valuation.

3. Material and methods

3.1. Data

For both RQs, an in-depth search of Web of Science sources will be used as a data collection method to gain a comprehensive understanding of the current state of knowledge in this area. Specifically, relevant articles, academic studies and research that address sustainability issues within the real estate market will be sought and identified. The main search criterion in the Web of Science will be set to search for publications within the last 5 years to ensure the highest relevance of the topic. Articles, expert studies and research will be analyzed according to the relevance of the content, methods used and results that are relevant to the real estate market. For RQ1, the focus will be on current major trends in real estate sustainability assessment, including its impact on the real estate valuation process. For RQ2, consideration will be given to the tools used in real estate sustainability assessment and how they relate to real estate valuation. Firstly, key words and phrases related to real estate sustainability assessment and real estate valuation will be identified. For an in-depth search of the sources, 15 keyword sequences will be compiled:

1. Sustainability, certification, market value.
2. Rating, LEED, trend.
3. BREEAM, energy efficiency, valuation.
4. Environmental audit, social factors, economic benefits.
5. Technology, renewable energy, environmental quality.
6. Buildings, sustainable investment, innovation.
7. Green roofs, ecological aspects, property value.
8. Energy, saving, sustainable.
9. Environment, asset value, social responsibility.
10. Modernization, environmental certificates, financial efficiency.
11. Energy intensity, social impact, economic growth.
12. Nature conservation, sustainable architecture, market differentiation.
13. Energy savings, lifestyle, economic benefits.
14. User comfort, green technologies, financial valuation.
15. Social economy, ecological value, market competitiveness.

Specifically, the top three most relevant scientific studies, articles and research on a given issue will always be sought.

3.2. Methods

After an in-depth search of Web of Science sources, a bibliometric analysis will be used to identify the most frequently used keywords, authors, institutions and journals in the field of real estate sustainability assessment and real estate valuation. The data analysis method for both RQs will be a co-occurrence analysis, which will be performed in VOSviewer software to visualize and analyze the co-occurrence relationships between keywords and concepts identified in the literature. The software will identify key themes, trends and tools in real estate sustainability assessment and their impact on real estate valuation. More specifically, the software will be entered with scholarly studies, articles and researches that will be extracted from the 15 keyword sequences.

These sequences will yield 14,118 articles, which will yield 150-259 keywords for the VOSviewer software, which will produce visualizations and diagrams that will in turn show us how trends and tools in real estate sustainability assessment relate to real estate valuation. Each VO will have a different diagram. For RQ1, the focus will be on the current major trends in real estate sustainability assessment including its impact on the real estate valuation process. For RQ2, consideration will be given to the tools used in real estate sustainability assessment and how they relate to real estate valuation. These diagrams will then be commented on verbally and compared with the sources from the in-depth research.

4. Results

4.1. Trends

For RQ1, an in-depth search of Web of Science sources was used as a data collection method to gain a comprehensive understanding of the current state of knowledge in this area. Specifically, relevant articles, scholarly studies and research that address sustainability issues within the real estate market were searched for and identified. For RQ1, the focus was on current major trends in real estate sustainability assessment, including its impact on the real estate valuation process. In addition, a co-occurrence analysis was used, which was conducted in VOSviewer software to visualize and analyze the co-occurrence relationships between keywords and concepts identified in the literature. The software identified key themes, trends and tools in real estate sustainability assessment and their impact on real estate valuation.

Recent trends in property sustainability assessment include the incorporation of technologies to reduce

energy consumption, use renewable energy sources and improve the social well-being of occupants. These trends reflect a growing emphasis on sustainable investment and efforts to reduce the environmental impact of the construction industry. There are currently a number of building sustainability rating systems and there are also several systematic reviews of building sustainability rating systems, including green building rating systems in particular (Lazar & Chithra, 2021). With the promotion of sustainable development and the concept of green buildings, green building rating systems are emerging and gradually attracting more and more attention. LEED (Leadership in Energy and Environmental Design) is a globally widespread and influential rating system, with research showing a growing trend year on year (Lei & Cui, 2022). In fact, it is difficult for any rating system to be globally relevant as LEED has been heavily criticized as an inappropriate tool in many parts of the world. This is due to many differences such as climatic conditions, natural resources and social, cultural and economic aspects of each region. Alyami (2020) investigated the applicability of LEED rating criteria across countries and found that criteria based on objective and subjective ratings were combined into one rating statement.

In recent years, there has been a growing interest in analyzing the energy performance of buildings using Life Cycle Energy Assessment (LCEA). Omrany et al. (2020), through a critical analysis, found that the current trend of applying LCEA in residential buildings suffers from considerable inaccuracy due to incomplete definition of system boundaries and the lack of consensus on operational and internal energy measurements. The regulations confirm the importance of retrofitting existing buildings or building new energy efficient residential neighborhoods. Therefore, modeling tools are needed to evaluate energy scenarios to improve urban management and planning, and several methods and tools have been developed. Such tools have been studied by Ferrando et al. (2020) in which they evaluated one of the most important UBEM tools, where the barriers to the adoption of UBEM tools are the need for a standardized ontology, a common 3D urban model, a standard data collection procedure and standard test cases. According to Ferreira et al. (2022), the LiderA method developed for commercial buildings can help designers, managers and users to design and manage more sustainable stores, where results show that it can improve the environmental performance of retail stores and support decisions to achieve maximum energy efficiency and

carbon neutrality.

The role of industry self-regulation in promoting sustainability has been increasingly recognized over the last two decades. As a result, voluntary certification standards are becoming increasingly common and are being introduced as an effective tool to promote greener practices in many industries. Leiringer (2020) examined the Building Environmental Assessment Method (BEAM) in terms of categories, criteria and weights, and considered sustainability assumptions and institutionalized practices in the building industry. The application of Building Information Modeling (BIM) provides new opportunities for carbon reduction in sustainable buildings. Liu et al. (2022), using macro-quantitative and micro-quantitative research methods of bibliometric analysis, found that there are five most popular areas for BIM research on carbon dioxide emissions in sustainable buildings in the green building industry: building life cycle assessment, sustainable materials, energy, efficiency, and building design and environmental strategies. This is confirmed by an experiment Arcuri et al. (2020) where real estate valuation analyzed the potential of combining Geographic Information Systems (GIS) and Building Information Models (BIM) in automated valuation methods through amortized replacement cost. Balasubramanian et al. (2021), through an empirical, multi-methodological case study assessment, found that greater adoption was seen for building information modeling and automation compared to others, such as cyber-physical systems and smart materials, with significant growth expected in the future for technologies related to blockchain and 3D printing.

Climate change is considered one of the greatest challenges facing humanity. Global efforts to reduce greenhouse gas emissions are taking place in sectors like economy or the construction industry. A study by Alazazmeh and Asif (2021) examined heating, ventilation and air conditioning (HVAC) systems with total energy consumption that significantly affect buildings, especially in hot and humid climates. Using a case study of a commercial organization's office building, it was found that the retrofit measures implemented reduced the building's energy load by 39%. Improvements in indoor environmental quality in various areas, such as thermal comfort, lighting, noise reduction and pollution abatement were also highlighted. In the research, Lambourne (2022) examined the impact of sustainability elements on the pricing of buildings and found a green premium of at least 1% on both the supply and demand side. Effective

The construction sector is slowly but steadily becoming the largest contributor to global carbon dioxide emissions, so construction businesses have an obligation to do their part to reduce carbon dioxide emissions. One way to do this is to develop the concept of green building, which is one of the solutions to sustainable development. The method according to Utomo et al. (2022), is inferential analysis, which aims to see how the effect of implementing a green building translates into its valuation, and it has been found that, according to the practice of developers of green building concepts, an increase in construction costs is

Given the growing interest in sustainable investments and the pressure to reduce the environmental impact of building, sustainability certifications are expected to play an increasingly important role in the property valuation process in the future.

Furthermore, a co-occurrence analysis was performed in VOSviewer software. The outputs of the co-occurrence analysis are shown in Figure 1.



Fig. 1. Co-occurrence analysis for RQ1. *Source:* own processing in VOS viewer software (2024).

The co-occurrence analysis shows that trends include rating systems, BIM, new technologies and the impact of sustainable investments. Within the valuation

itself, they show the greatest relationships with costs and projects. The original value of the property lies in the technical innovations and what their potential

return and overall use is. Sustainable real estate shows the strongest relationships with LEED certification, rating systems, life cycle assessments, and energy issues where great care is taken to keep energy costs as low as possible, most often addressed by renewable energy sources. These renewables show strong relationships not only with revenue and costs, but also with carbon emissions, CO₂ emissions and emissions in general.

4.2. Tools

For RQ2, an in-depth search of Web of Science sources was used as a data collection method to gain a comprehensive understanding of the current state of knowledge in this area. Specifically, relevant articles, scholarly studies and research that address sustainability issues within the real estate market were searched for and identified. For RQ2, the focus was on the tools that are used in real estate sustainability assessment and how they relate to real estate valuation. In addition, a co-occurrence analysis was used, which was conducted in VOSviewer software to visualize and analyze the co-occurrence relationships between keywords and concepts identified in the literature.

In addition to certifications, there are other tools and methodologies for assessing the sustainability of real estate. These include environmental audits, energy assessments and others. They allow a more detailed assessment of the sustainability of a property and the identification of areas for improvement. At the same time, such tools can influence the market value of real estate, especially in terms of operating costs and economic efficiency. In this respect, green certificates, which certify the production of electricity from renewable sources and allow organizations to demonstrate their commitment to clean energy, have gained considerable popularity. A study by Chrysikopoulos et al. (2024) used bibliometric analysis and power analysis, and through a power analysis found that the four main research themes are renewable energy policy, sustainable renewable technologies and market dynamics, technological innovation and green certificate trading, and renewable energy investment strategies. Sustainability assessment tools can play an important role in this respect, namely certificates that assess the sustainability of urban buildings and thus represent points to be considered in the most effective way. Studies by Sanei (2022) examined the effectiveness of BREEAM (The British Building Research Establishment Environmental Assessment Method), one of the most advanced and

widely used certifications, and found significant differences in the priority of factors and the level of importance placed on each factor between the BREEAM assessment process and factors in the audit literature. In a case study by Sisman and Aydinoglu (2022), the authors tested the bulk valuation of sustainable properties when high model performance is desirable for the development of sustainable property management strategies and found that value prediction models in terms of model performance clusters based on geographic value were more successful than the entire area studied by the model.

From a global perspective, the environmental sustainability of building systems has always been a hot research topic. Xie et al. (2023) proposed and adopted the LCA-Emergy-ANN framework to assess and analyze the sustainability of an airport construction system, using artificial neural networks and sensitivity analysis, found that the emergence of building materials and emergence of an operational phase play a crucial role. In recent years, with the intensification of climate change, the development of Low Carbon Buildings (LCB) has gained great momentum and Building Information Modelling (BIM) is considered the most promising path. H. Liu et al. (2023), using a hybrid literature review method consisting of quantitative and qualitative analysis, found that LCB information model studies were mostly adopted from the life cycle perspective followed by the design phase, while some studies focused on the LCB information model in the operational phase, and demolition was relatively small. Currently, research focuses on how the latest methods and technologies can reduce carbon dioxide emissions during the life cycle of a building, e.g. the BIM-LCA method. In contrast, research by Arduin et al. (2022), using a systematic literature review to validate LCA methodology trends, found that soil-based construction performs better than conventional materials in various impact categories. Zhang et al. (2020) reviewed the life cycle assessment (LCA) method and its application to the assessment of rehabilitation and concluded that resource scarcity and environmental pollution have emerged as social issues of global significance and significantly affect sustainability. Finally, LCA-based remanufacturing and energy, as well as environmental and economic assessments were systematically described to better understand and apply LCA and promote remanufacturing. LCA has also been addressed in the research of Mesa et al. (2021), where they used the PRISMA method to analyze research gaps in

methodological and design tools to improve LCA analysis, indicators and linkages with new trending concepts such as circular economy and Industry 4.0. The PRISMA method has also been used by research of Packer & Zanasi (2023), who noted that a detailed framework specifically addressing the social impacts of bioregions was not found in the literature.

The External Thermal Insulation Composite System (ETICS) is a widely used solution in EU countries to increase the energy efficiency of buildings. Research by Michalak (2021) analyzed the environmental indicator of global warming and found that there are significant differences between the values of the global warming indicator and the values of other environmental indicators that can be used to assess and monitor the stability of buildings in the future. Modular Integrated Construction (MiC) is an innovative technology that minimizes the detrimental effects of construction in terms of material resources, energy consumption and environmental impact, but also reduces construction time and costs. Research by Nguyen et al. (2021), which used bibliometric search combined with quantitative and qualitative analysis, summarized the current research directions. In contrast, Imam et al. (2019) used the System Advisor Model renewable energy modelling software to perform a techno-economic feasibility analysis of a grid-connected solar photovoltaic (PV) system for residential homes and found that the proposed system could produce 87% of the electricity demand of the home and the calculated energy cost and net present value showed competitive values. In the experiment of Unel and Yalpir (2023) a sustainable mass pricing system for taxation purposes was successfully tested and found to be sustainable. Related research by Wang et al. (2021) using the Laffer curve found that the Laffer curve is consistent with the overall situation in the V4 countries. As sustainable urban development is now a global goal, among the many assessment tools and methods available, multi-criteria decision analysis (MCDA) is one of the most commonly used approaches to support sustainable decision making and sustainable urban development and architecture (Mecca, 2023). Environmentally sustainable real estate can influence the economic outcome. Devine and Yonder (2023), using an instrumental variance approach, find that greener portfolios attract a market value premium over operating profit, carry less systematic risk, and are less subject to uninformed trading.

Next, a co-occurrence analysis was performed in the VOSviewer software, which is depicted in Figure 2.

The covariance analysis shows that there is a certain causal relationship between sustainable certificates and the market value of real estate. The same can be said for commercial buildings that house businesses. The LEED and BREEAM instruments show the strongest relationships and are closely related not only to sustainability but also to emissions. It is emissions that are associated with a large part of the publications already published, this being a very hot topic that has been addressed extensively in the recent years. Emissions show the highest correlations with renewable energy, building energy performance and economic growth. Economic growth in particular is strongly linked to sustainable development goals, technological innovation, and environmental regulation. Economic growth is also very often addressed in conjunction with environmental degradation. Renewable energy sources and their use are closely linked to green technology innovation and environmental quality. If we focus on valuation itself, sustainability and real estate valuation show some causal relationships, but they are not as strong. Hence, it can be concluded that relatively little literature addresses how the tools used in real estate sustainability assessment affect real estate valuation itself. There are relationships with tools such as BIM and energy conservation tools. The potential for sustainability in property valuation issues is also very positive.

5. Discussion

What are the current major trends in the assessment of property sustainability and how do these trends affect the property valuation process?

From an in-depth search of sources, it was found that recent trends in the assessment of property sustainability include technologies to reduce energy consumption, use renewable energy and improve the social well-being of residents. These trends are a logical outcome of increasing energy prices and their impact on the environment. In contrast to the research of Ellington et al. (2023), where in-depth research was involved, a larger number of studies were considered to gain a more comprehensive understanding of the issue. Heating, Ventilation and Air Conditioning (HVAC) systems that have significantly reduced the energy burden of a building have been investigated or the International Performance Measurement and Verification Protocol (IPMVP) has been widely used. Interesting concepts for rating sustainable buildings are emerging, with LEED still one of the most widely used. This system, however, has also been criticized in

many parts of the world and, after a deeper analysis of the issue is apparent, as not all parts of the world have similar climatic conditions, natural resources and social,

cultural and economic aspects. In research Alyami (2020) where the applicability of the different LEED rating criteria across countries was examined.

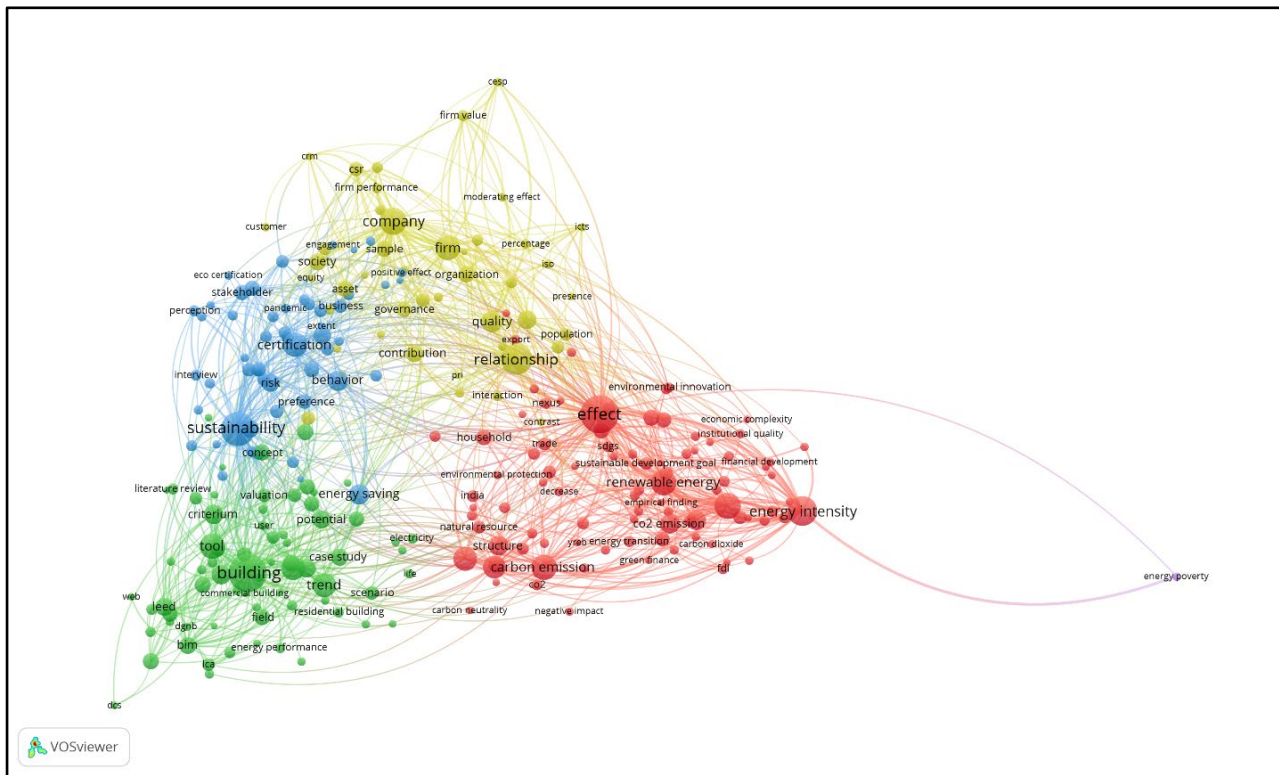


Fig. 2. Co-occurrence analysis for RQ2. *Source:* own processing in VOSviewer software (2024).

In recent years, there has also been a growing interest in building energy performance analysis, but its application suffers from incomplete definitions of system boundaries. In contrast to research Zhang et al. (2023), it was found that not every system can be energy efficient. Furthermore, UBEM tools and the LiderA method, which assesses the environmental performance of retail stores and carbon neutrality, are also currently used. The Building Environmental Assessment Method (BEAM) also appears to be very effective. Related to this method is the application of BIM, where the hot topic is research on the building life cycle, sustainable materials, energy, efficiency, and building design and environmental strategies. BIM has also been explored from a real estate valuation perspective and is expected to see significant growth in blockchain-related technologies in the future. In conjunction with research by Liang et al. (2021), many more papers have been engaged to explore the issue in more depth.

There are systems and trends in the assessment of building sustainability and there are relationships between sustainability and the market value of real

estate, but the co-occurrence analysis shows that the valuation of sustainable real estate itself does not have a clearly defined framework. The original value of the property lies in the technical innovations and what the potential return. However, according to the research by Utomo et al. (2022), according to the practice of developers of green building concepts, the increase in construction costs is not always associated with a decrease in operation and maintenance costs and an increase in property value. This, however, is contradicted by research Lambourne (2022), where the impact of sustainability elements on building valuations is at least 1%, both on the supply and demand side. Sustainable properties show the strongest relationships with LEED certification, rating systems and life cycle assessments. Given the growing interest in sustainable investments and the pressure to reduce the environmental impact of building, sustainability certifications are expected to play an increasingly important role in the real estate valuation process in the future.

These relationships are also explained in the following diagram.

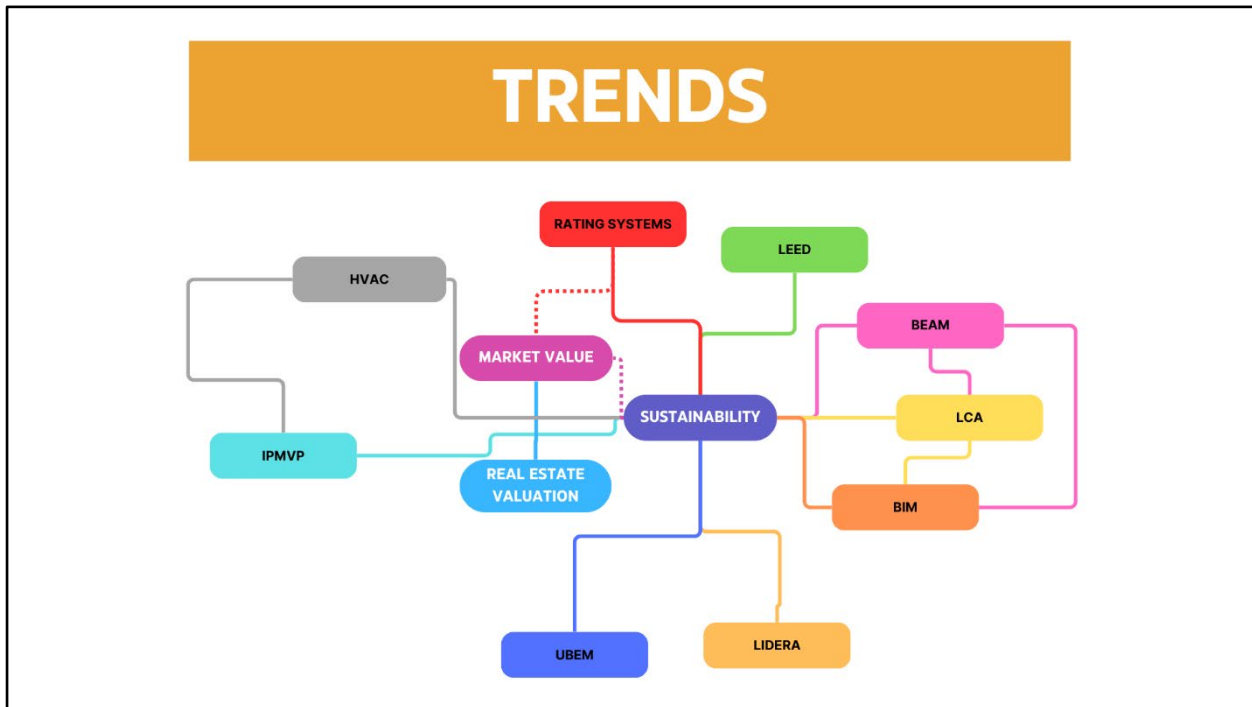


Fig. 3. Diagram for RQ1. Source: own processing (2024).

What are the most effective tools for assessing property sustainability and how do they relate to property valuation?

An in-depth search of sources revealed that there are other tools besides certification, such as environmental audits and energy assessments. These tools allow for a more detailed assessment of the sustainability of properties and can influence the market value of properties in terms of economic efficiency. Tools can also include green certificates, which are linked to renewable energy. Currently, research is mainly concerned with renewable energy policy, sustainable renewable technologies and market dynamics, technological innovation and trading of green certificates. In contrast to research Su & Hong (2022) A larger sample of studies and research has been secured.

One of the most effective tools is BREEAM certification, which is one of the most advanced certifications. Other tools include the LCA-Energy-ANN framework, and in recent years, the development of low carbon buildings (LCB) has gained great momentum, with building information modeling (BIM) considered the most promising route. This issue has also been explored by Liu et al. (2024), but in our research, the focus was on developing the issue in more depth including a more comprehensive understanding. Other tools may include remanufacturing based on life cycle assessment (LCA) and LCA itself, which is, for example, in conjunction with the PRISMA method.

External Thermal Insulation Composite System (ETICS) is a widely used solution in EU countries to increase the energy efficiency of buildings. Recently, innovative Modular Integrated Construction (MiC) technology has been included among the tools to minimize energy consumption, costs and construction time with respect to the environment.

Research Nguyen et al. (2021) summarized the current research directions, but our research focused on a broader portfolio of areas where specific research directions were selected as having the highest trend. Another tool that, in our opinion, is of great interest is the System Advisor Model software, where renewable energy sources can be modelled in a techno-economic analysis. Such sustainable systems have even been tested in the framework of sustainable pricing.

From the co-occurrence analysis, it was found that there is a certain causal relationship between sustainable certificates and the market value of real estate. The same can be said for commercial buildings that house businesses. LEED and BREEAM have the highest correlations and are closely related to the market value of real estate. Compared to the co-occurrence analysis Ali et al. (2022) we secured a much larger number of publications that yielded a much larger number of keywords that were used, thus ensuring a larger number of co-occurrence relationships and greater connectivity between clusters. If we focus on the valuation itself, sustainability and real estate valuation show some causal relationships, but

they are not as strong. Hence, it can be concluded that relatively little literature addresses how the tools used in real estate sustainability assessment affect the real

estate valuation itself. There are, however, relationships with tools such as BIM and energy conservation tools.

These relationships are explained in the following diagram.

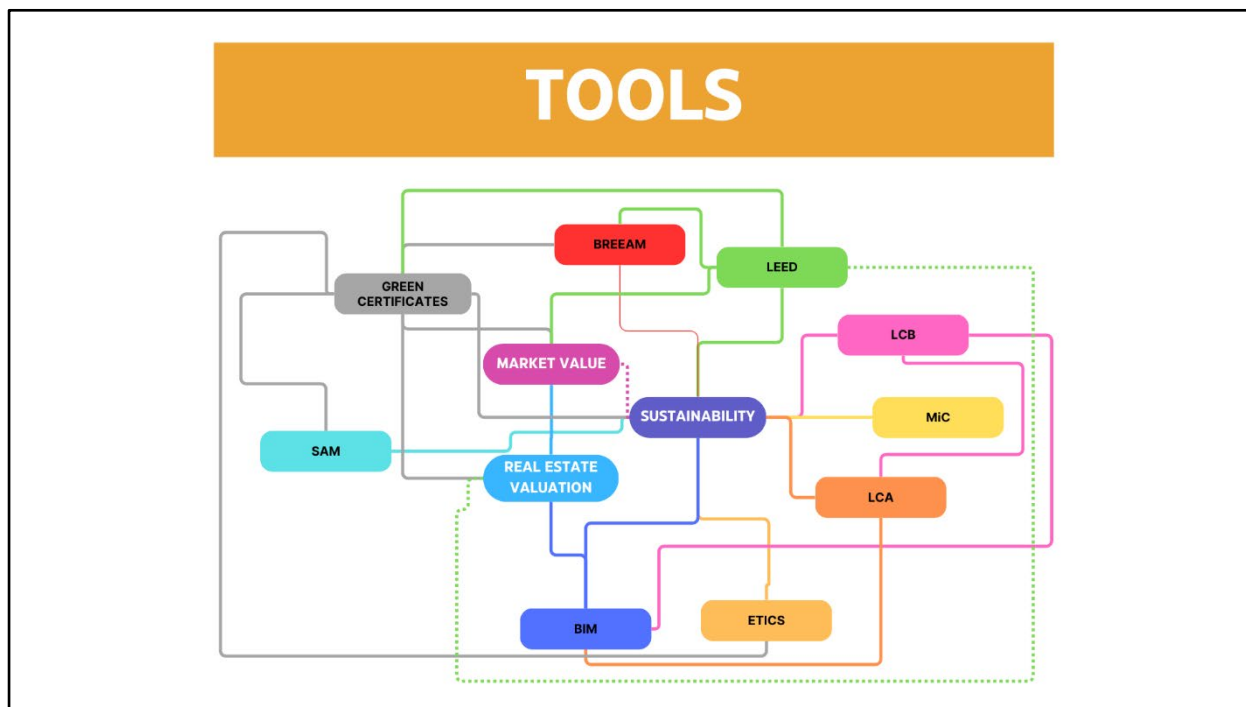


Fig. 4. Diagram for RQ2. Source: own processing (2024).

It can therefore be assumed that currently sustainable real estate does not have a valuation concept in itself, nor is this topic the main focus of research, but the potential for sustainability in real estate valuation issues is positive. On the other hand, Oktabec & Wills (2024) have developed a scoring tool that allows real estate companies to measure and evaluate the environmental sustainability of properties during the purchasing process.

6. Conclusions

The aim of the research was to find out what the current trends and tools in the field of real estate sustainability assessment are and to find out their relevance for real estate valuation. This research may be of value to real estate valuation experts or to researchers working on sustainability issues in real estate valuation.

Since sustainability has been a key topic in the construction and real estate industry in recent years and more and more emphasis is being placed on its integration into the real estate valuation process, it was necessary to determine the current state of knowledge on the issue and whether sustainability is actually reflected in the real estate valuation process. From the research, it was found that current trends in real estate

sustainability valuation include technologies for reducing energy consumption, use of renewable energy, improving social well-being of occupants, the HVAC system, building energy performance analysis, UBEM, LiderA method, BEAM method, BIM and among the most widely used systems is LEED certification. The co-occurrence analysis shows that the valuation of sustainable real estate itself does not have a clearly defined framework.

Tools include environmental audits, energy assessments, green certificates, sustainable renewable technologies, technological innovation, BREEAM certification, LCA-Emergy-ANN framework, LCB, LCA, PRISMA, ETICS, MiC and the use of System Advisor Model software. It is the LEED and BREEAM certifications, however, that show the greatest relationships with market value. Nevertheless, even these tools have been criticized in some parts of the world, as there are different climatic conditions, different natural resources and different economic aspects in various parts of the world. Sustainability itself has a relationship with property valuation, but it is not a strong one, and therefore it can be assumed that currently sustainable properties do not have a valuation concept themselves, nor is this topic a major research

topic. On the positive side, there is potential for sustainability in real estate valuation issues, where sustainability certifications are expected to play an increasingly important role in the real estate valuation process in the future.

A limitation of the research is the fact that many publications do not directly address the process of sustainable property valuation, but this fact is a potential for a new line of research that would specifically address the process of sustainable property valuation. The result could be a method of valuing sustainable real estate that could be groundbreaking, giving potential to a wide range of researchers working in this area. Another limitation of the research is the possibility of using a wider range of tools for bibliometric analysis, but the results obtained from our research are sufficient to comprehensively assess the knowledge of the subject. In summary, it can be concluded that the objective of the research has been met.

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