STUDY ON THE RESILIENCE IN THE REAL ESTATE INDUSTRY IN THE CONTEXT OF TRANSITION FROM INDUSTRY 4.0 TO INDUSTRY 5.0

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Abstract
This study examined the integration of resilience strategies in the real estate industry, taking into account increasing climate risks, economic changes and technological advances. The work highlights the importance of Industry 4.0 and 5.0 and shows how they impact workflow optimization, improving human-machine collaboration, and how resilience measures can not only protect assets but also create competitive advantages by meeting the sustainability preferences of investors, tenants and owners. Despite advances in research, gaps remain in fully exploring these strategies, especially in adapting the rationale of Industry 5.0. The study calls for interdisciplinary research to improve the theoretical and practical applications of resilience to ensure long-term profitability and relevance in the real estate market. The findings contribute to broader discussions on sustainable urban development and the transformative role of new technologies.

Key words: Real estate, Resilience, Industry 5.0, BIM, Climate change

JEL Classification: 010, R30

I. INTRODUCTION

The importance of integrating resilience as a fundamental principle in portfolio management and not just as a side effect has been underlined by the diversification and intensification of risk factors that have affected the real estate sector in recent years. The recognition that climate-based risks, as reflected in the frequency and severity of extreme weather phenomena such as wildfires, hurricanes and floods, have become an undeniable problem. These phenomena not only pose immediate hazards to properties but also lead to a surge in insurance costs, compelling investors to consider the resilience and adaptive capacity of real estate investments as a priority. (Wilkinson et al., 2014) The development of an efficient resilience policy as a crisis policy is an essential factor at national and communal level in order to better deal with foreseeable crises and to be better prepared in the event of a crisis. (Kauko, 2023)

The necessity to confront climate risk is matched by the critical need to address the significant role of the real estate sector in contributing to global CO2 emissions. The shift towards sustainable assets, driven by global efforts to combat climate change, is identified not just as an environmental imperative but also a strategic economic consideration. It is highlighted that properties focused on sustainability are more efficient, carry higher value, and are likely to offer superior customer experiences. With the international movement towards a net-zero economy, the real estate sector is confronted with substantial financial challenges for failing to transition, indicating potential significant devaluations for entities that neglect carbon emission reductions. (Jackson & Orr, 2021)

Furthermore, the emergence of risks not directly related to climate, such as changes in work models following COVID-19, has led to a reassessment of the traditional understanding of 'core' investments, exposing increased vulnerabilities (Wang, 2023). The research presented herein is centered around a pivotal question: In what ways can resilience be embedded within the operational and investment strategies of the real estate industry to effectively manage a wide array of emerging risks? This inquiry hypothesizes that adopting a holistic approach to resilience, not just as an emergency response mechanism but as a crucial component of strategic decision-making and asset valuation, is essential for the enduring prosperity and viability of the real estate sector. The

objective of this study is to illustrate that resilience, amidst the certainty of future uncertainties, is not merely advantageous but vital for the advancement of the real estate domain. (Kaklauskas et al., 2021)

To navigate effectively through these challenges and maintain a competitive stance in the marketplace, it is imperative that specific methodologies for augmenting resilience are employed. The deployment of sophisticated technologies in risk analysis and management, inclusive of Big Data usage, alongside the principles of Industry 4.0 and 5.0, as well as the application of artificial intelligence (AI) for the forecasting of market trends, is identified as crucial. These advancements in technology are acknowledged for their capacity to prepare and anticipate potential risks, thereby optimizing operational efficiencies and enhancing decision-making processes within the real estate sector. (Baum, 2017)

The employment of Big Data analytics is recognized for its ability to compile and analyze ex-tensive datasets related to market trends, climate-related risks, and consumer behaviors, providing unparalleled insights into potential vulnerabilities and opportunities. This approach, driven by data, supports the development of informed strategic planning and risk management, enabling stakeholders to make decisions that are comprehensive and reflective of market dynamics. Moreover, the adoption of technologies associated with Industry 4.0 and 5.0, including the Internet of Things (IoT), robotics, and smart automation, is seen as instrumental in elevating the resilience of real estate assets (Pitz, 2023). The benefits of these technologies are noted in terms of enhancing efficiency, diminishing operational costs, and elevating the adaptability of properties to both environmental and economic shifts. Real-time monitoring and management of properties are facilitated by these technologies, ensuring that optimal performance is maintained and risks related to physical and operational inefficiencies are mitigated. (Munawar et al., 2020)

The role of artificial intelligence in fostering resilience within the real estate industry is also highlighted. Through AI algorithms, the prediction of market fluctuations, identification of emerging trends, and simulation of various scenarios' impacts on property values and investment returns are made possible. In times of climate change and the resulting economic instability, this ability to predict is of great importance, as predictive analytics serves as the basis for investment strategies, asset management and sustainability efforts. (Abioye et al., 2021)

In summary, for the real estate sector to assert its position in the market amidst a broadening landscape of risks, the necessity of integrating advanced technologies for risk management, analysis, and market prediction is emphasized. The strategic incorporation of Big Data, Industry 4.0 and 5.0 technologies, and AI into real estate operations marks a transition towards a more resilient, adaptive, and proactive industry. This embrace of technological advancements not only prepares the sector to face future challenges but also sets the foundation for sustainable growth and enduring success.

II. LITERATURE REVIEW

EVOLVING THREAT LANDSCAPE

Rising sea levels and flooding

The escalating frequency of coastal floods across the United States in recent decades, coupled with the ongoing rise in sea levels, signals an urgent need for research and action within the realm of real estate, particularly regarding the physical risks associated with rising sea levels and flooding. This phenomenon not only poses a significant threat to coastal infrastructure but also has profound equity implications, especially for residents of low-lying affordable housing. These individuals, often low-income and residing in older, poorly constructed buildings, find themselves at an increased risk of experiencing the detrimental impacts of sea level rise (SLR) and coastal flooding. In a pioneering nationwide assessment of the recent and future risks posed to affordable housing by SLR and coastal flooding in the United States, researchers have utilized high-resolution building footprints along with probability distributions for local flood heights and SLR to pinpoint coastal states and cities where affordable housing - both subsidized and market-driven - is most vulnerable to flooding. This assessment provides very important insights into both the expected number of affordable housing units that may be at risk from extreme coastal water levels and the frequency with which these units may be at risk of flooding. (Buchanan et al., 2020)

What is very worrying is that current projections indicate that the number of affordable housing units in the United States that may be exposed to such risks will more than triple by 2050. States such as New Jersey, New York, and Massachusetts are identified as having the highest number of units exposed to extreme water levels, both in absolute terms and relative to their total affordable housing stock. Moreover, several top-ranked cities could see a significant number of coastal flood events surpassing the elevation of affordable housing sites annually. Given that the top 20 cities comprise 75% of the overall exposure, targeted, strategic, and city-level interventions could potentially mitigate much of the risk to the coastal-area affordable housing stock. This focused approach suggests that addressing the challenges posed by SLR and coastal flooding to affordable housing is not only a

matter of national concern but also a localized issue that requires tailored solutions to protect vulnerable populations and preserve essential housing infrastructure. (Buchanan et al., 2020)

This current state of research underscores the critical need for concerted efforts to address the physical risks associated with rising sea levels and flooding, particularly as they impact affordable housing. The findings highlight the importance of integrating climate resilience into housing policy and urban planning to safeguard against the escalating threat of coastal flooding, ensuring the protection and sustainability of affordable housing stock for the most vulnerable segments of the population.

Heat stress and increased cooling demand

The ongoing global climate change phenomenon, characterized by an increase in the average air temperature, is leading to more intense and frequent heatwaves across the globe, including regions such as northern Europe not traditionally associated with high heat stress. This rise in temperatures poses a significant challenge to the real estate sector, particularly concerning the overheating risk and increased cooling demand in residential buildings. The health of occupants and the indoor conditions during summertime, especially in buildings without mechanical cooling systems, are directly impacted by these climatic changes. Furthermore, the energy consumption of buildings, a major contributor to climate change through greenhouse gas emissions, underscores the necessity to examine the implications of these temperature increases on residential buildings' energy demand and overheating risks. (Velashjerdi Farahani et al., 2021)

In a recent study focusing on this urgent issue, dynamic energy simulations and assessments of indoor conditions were conducted for both a new and an old apartment building in southern Finland. This study utilized two climate scenarios projected for 2050—one representing average weather conditions and the other modeling extreme weather conditions—to evaluate the risk of overheating and the effectiveness of various mitigation measures. Among the strategies assessed were building orientations, the use of blinds, site shading, window properties modifications, installation of openable windows, split cooling units, and enhancements in ventilation cooling and ventilation boost systems. The findings from this study reveal a high risk of overheating in both the current climate conditions and the future projected average and extreme weather scenarios, with indoor conditions occasionally reaching levels detrimental to occupants' health. While openable windows and improved ventilation cooling with a ventilation boost were found to be effective in ameliorating indoor conditions under both current and future climatic conditions, the split cooling unit installed in the living room emerged as the only solution capable of entirely preventing overheating across all spaces. Notably, this was achieved with a relatively minor increase in energy usage. (Velashjerdi Farahani et al., 2021)

The present findings underscore the urgency and need for the real estate industry to adopt comprehensive and efficient cooling strategies that could counteract the effects of global warming and maintain or improve the health and comfort of building occupants. The study highlights the importance of incorporating adaptive measures and technologies that could reduce the risk of overheating while minimizing additional energy demand, thus contributing to the broader efforts to combat climate change. The findings serve as an important reference for policy makers, urban planners and investors in developing strategies that are consistent with the two primary objectives of improving indoor comfort and sustainability in the face of rapidly increasing global temperatures.

Extreme weather events

The contemporary discourse on climate finance underscores the escalating concern regarding climate change's tangible impacts on global economies and societal structures (Denton, 2024). Climate change is exacerbating severe natural disasters. Developing countries face major challenges, including displacement, emigration and the need to find viable solutions to mitigate economic and social consequences. These concerns have implications for the realm of financial markets, where investors are increasingly recognizing the significant impact of climate change on asset valuation. The introduction of climate finance, a concept developed by Nordhaus in the 1970s, marked a paradigm shift in understanding the interface between the physical processes of climate change and the real economy. (Akhtar, 2020; Calabrese et al., 2024; Spencer, 2023)
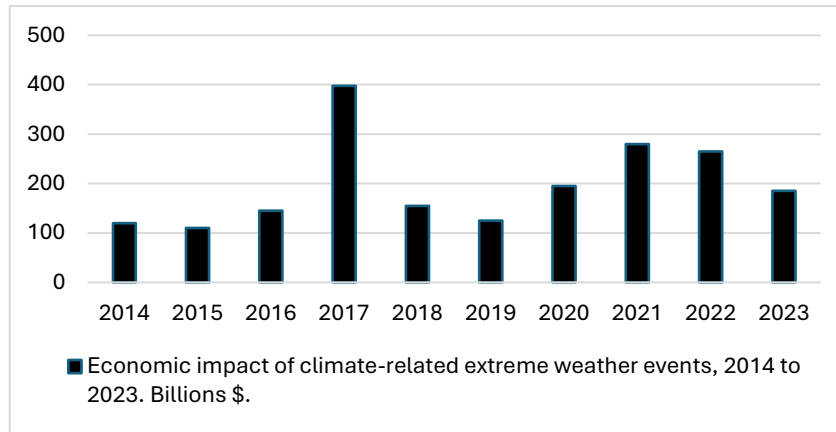
Figure 1: Denton, 2024.

It is not the amount of damage that is problematic, but also the concentration on countries or regions. In the following figure, we see some strong economies that can afford the climate-related damage. However, economically weaker countries are overwhelmed by lower amounts of damage in absolute terms.

Rank	Country	Sum of economic impact 2014–2023 (Billion, USD 2023)
1	United States	$934.7
2	China	$267.9
3	India	$112.2
4	Japan	$90.8
5	Puerto Rico	$87.3
6	Germany	$65.4
7	Italy	$35.0
8	Australia	$33.7
9	France	$29.4
10	Brazil	$24.8

Figure 2: Denton, 2024.

Climate change, an empirical phenomenon characterized by partial knowledge, historical observations, and future projections, demonstrates a clear linkage between greenhouse gas (GHG) emissions and global temperature rises. However, the predominantly long-term impact of temperature increases, an essentially irreversible phenomenon, necessitates a forward-looking approach to economic policy. Nordhaus highlighted the anthropogenic economic activities driving climate change, advocating for policies that harmonize economic growth, wealth creation, and climate sustainability. Among the strategies proposed, taxing CO_2 emissions emerges as a primary option, albeit with significant implications for production and growth, particularly affecting developing countries that would see minimal internalization of benefits. Developing nations, experiencing higher growth rates and CO_2 emissions, find limited incentive to transition from fossil fuels, given their cost-effectiveness and reliability compared to alternative energy sources. Thus, a second-best strategy encompasses a holistic approach, including mitigation, adaptation, monitoring, and technological innovation to reduce emissions and reallocate resources effectively. (Akhtar, 2020; Calabrese et al., 2024; Spencer, 2023)

The significance of financial markets in confronting the challenges posed by climate change cannot be overstated. These markets act as crucial platforms for aggregating information, which is essential for making informed decisions regarding climate-related risks and opportunities. They play a pivotal role in the sharing and diversification of risks, enabling investors and stakeholders to mitigate potential losses from climate-induced events. Furthermore, financial markets are instrumental in facilitating the transition towards sustainable production practices. This is achieved through the reallocation of resources, directing capital towards investments that are not only environmentally sustainable but also economically viable. (Akhtar, 2020; Calabrese et al., 2024; Spencer,

2023)

Climate change poses risks, to markets and impacts the real estate sector in both commercial and residential aspects where they intersect with each other seamlessly. Real estate investments are vulnerable to climate related risks such as property damage caused by weather conditions and depreciation of property values in high risk areas. Financial markets have been proactive, in evaluating and managing these risks effectively. They've already considered the effects of climate change, on asset values and investment choices by thinking about how it can affect property prices and insurance costs among things in the investment world. They aim to encourage markets to embrace climate approaches in real estate by valuing climate risks appropriately. This involves investing in eco infrastructure and buildings well as making structures more resilient, to extreme weather conditions. The way the financial industry deals, with climate risks can impact policy choices that support the introduction of rules promoting sustainability and risk management, in real estate development and operations. (Akhtar, 2020; Calabrese et al., 2024; Spencer, 2023)

The escalating impacts of climate change on the real estate sector underscore the urgent need for real estate companies to develop and implement robust resilience strategies. As climate-related hazards such as sea-level rise, hurricanes, floods, and wildfires become more frequent and severe, the vulnerability of both commercial and residential properties to physical damages and value depreciation intensifies. This necessitates a paradigm shift in how real estate companies approach property development, management, and investment. Resilience strategies are essential not only for safeguarding assets but also for ensuring their long-term sustainability and profitability.

For real estate companies, resilience entails adopting comprehensive risk assessment and management practices that consider the full spectrum of climate-related threats. This involves integrating climate risk analysis into investment decisions, enhancing the structural resilience of buildings to withstand extreme weather events, and incorporating adaptive features that can respond to environmental changes. Furthermore, there is a growing emphasis on green building standards and certifications, which reflect a property's environmental performance and resilience to climate impacts. These measures not only reduce the risk of property damage and associated financial losses but also align with increasing investor and tenant demand for sustainable and climate-resilient properties. Moreover, real estate companies must engage in proactive collaboration with governments, communities, and the wider industry to develop and enforce policies and standards that promote climate resilience. This includes participating in urban planning processes to ensure that development is aligned with broader climate adaptation goals, investing in community resilience projects, and advocating for the adoption of sustainable construction practices and materials. (Akhtar, 2020; Calabrese et al., 2024; Spencer, 2023)

Sustainability standards

The domain of Construction Investment and Real Estate Development (CIRED) is increasingly aligned with the urgency to adopt and enhance sustainability standards. The research literature across this field, utilizing an interdisciplinary approach that includes environmental psychology, building life cycle analysis, and a suite of advanced metrics such as bibliometrics and scientometrics, offers a comprehensive perspective on the evolution of sustainability practices within real estate and construction. This body of work underscores a pivotal shift towards embedding sustainability at the core of CIRED projects, driven by a global recognition of environmental responsibilities and the need to mitigate climate change impacts. (Ionașcu et al., 2020; Hiep et al., 2021; Kaklauskas et al., 2021)

An examination of the research literature reveals a systematic development of the CIRED topic model, which serves as a critical tool for quantitative analysis in this arena. The focus is on understanding how sustainability standards are integrated into real estate and construction practices, reflecting on the sector's dynamic response to the growing demands for environmental stewardship. The literature review, derived from a broad array of keywords and selection criteria, spans construction investment, real estate development, civil engineering, along with a focus on residential, industrial, commercial, land, and special purpose real estate. This review critically assesses the interplay between sustainability standards and various property types, exploring their risks, strategies, and trends. (Ionașcu et al., 2020; Hiep et al., 2021; Kaklauskas et al., 2021)

One of the key insights from the research literature is the identification of sustainability as a central theme in the CIRED sector's evolution. This includes innovative analyses that consider the life cycle of CIRED projects, stakeholder interests, and the influence of external environmental factors. The literature emphasizes the importance of transparency and the role of Sustainable Development Goals (SDGs) as benchmarks for the sector's contribution to sustainable cities and communities (SDG 11), climate action (SDG 13), and decent work and economic growth (SDG 8). (Ionașcu et al., 2020; Hiep et al., 2021; Kaklauskas et al., 2021)

Despite a growing commitment to sustainability, the research literature points to a significant gap between stated aspirations and tangible actions within the real estate sector. This discrepancy highlights a need for a strategic, culture, and tool-based overhaul to transform sustainability commitments into concrete outcomes. The

analysis suggests that while there is an expressed interest in adhering to SDGs, the actual integration of these goals into business models remains limited. Most entities in the real estate sector report their sustainability goals qualitatively, with a scarcity of quantitative Key Performance Indicators (KPIs) to gauge the achievement of priority SDGs. This review of the research literature on CIRED and sustainability standards reveals a critical need for the sector to evolve its approach to sustainability. It calls for a deeper integration of sustainability standards into the fabric of real estate and construction projects, moving beyond nominal commitments to actual, measurable outcomes. The transition towards more sustainable practices not only addresses the environmental imperative but also aligns with the shifting expectations of investors, tenants, and broader societal stakeholders. As the CIRED sector continues to adapt and innovate, the emphasis on sustainability standards is set to redefine its operational and strategic paradigms, ensuring resilience and relevance in a rapidly changing global context. (Ionașcu et al., 2020; Hiep et al., 2021; Kaklauskas et al., 2021)

Resilience measures

In the course of conducting this literature review, it was imperative first to identify the key threat factors that challenge the sustainability and operational stability of real estate companies. This foundational step allowed for a comprehensive understanding of the external pressures, including environmental, regulatory, and market-driven risks, that these entities face in today's rapidly evolving landscape. By pinpointing these critical threats, the review sets the stage for a nuanced exploration of how the sector can navigate these challenges.

Following this initial identification of threat factors, the literature review now shifts focus towards a detailed discussion on relevant resilience measures adopted by real estate companies. This next phase of the review will delve into the strategic, operational, and technological adaptations that firms are implementing to enhance their resilience against the identified threats. It will examine the efficacy of various sustainability practices, risk management strategies, and innovation-driven solutions that real estate entities are employing to not only mitigate risks but also to capitalize on new opportunities presented by a sustainability-focused market landscape. This segment aims to provide insights into how real estate companies are redefining their approaches to ensure long-term viability and success in the face of mounting environmental and socio-economic challenges.

III. RESEARCH OBJECTIVS AND METHODOLOGY

SELECTION OF RELEVANT LITERATURE

In conducting a systematic literature review on the topic of "Resilience in Relation to the Real Estate Industry," a methodical approach characterized by several consecutive steps was adopted. Initially, the research question was precisely formulated to clearly delineate the focus of the review, concentrating on the investigation of the effectiveness of resilience strategies within the real estate sector. Subsequently, specific inclusion criteria were established, encompassing thematic relevance, publication date to ensure the currency of the research, the quality of the study, and the availability of full texts.

The literature search was systematically carried out across multiple scientific databases and libraries, including Google Scholar, PubMed, and ScienceDirect, utilizing keywords such as "resilience", "real estate industry", "climate change adaptation", "risk management", and "sustainable development" in various combinations. This was aimed at maximizing the breadth and depth of the research. Following this, the identified studies were screened based on their titles and abstracts to assess their relevance. The full texts of publications deemed relevant were then meticulously reviewed to confirm their suitability for inclusion in the review.

From the selected studies, pertinent information was extracted, including details on study design, resilience interventions, populations studied, methods of measuring industry resilience, and the outcomes achieved. An assessment of the quality of the included studies was conducted to ensure the reliability and validity of the research findings. This included evaluating the methodological rigor, sample size, and the appropriateness of statistical analyses.

Data from the individual studies were synthesized and analyzed to identify commonalities, differences, and the overall effectiveness of resilience strategies in the real estate industry. The results of the literature review were then summarized in a structured report. This report provides a comprehensive overview of the resilience methods examined, the main findings of the studies, and conclusions regarding the effectiveness of resilience strategies in improving the adaptability and sustainability of the real estate industry. This systematic approach ensures that the literature review was comprehensive, transparent, and reproducible, thus providing a sound basis for evaluating current research on resilience strategies in the real estate industry.

The objective of this study is to analyze the potential for implementing Industry 4.0 and Industry 5.0 in the construction industry, as well as to explain their possible effects, using empirical research based on existing scientific literature. As digitization is a complex phenomenon across various sectors, the construction industry is

no exception, needing to adapt its workflows, optimize processes, and improve production efficiency through the use of new technologies.

This paper's chosen methodology includes reviewing similar studies from the literature on Industry 4.0 and Industry 5.0 in the construction sector as well as already established concepts such as Building Information Modeling (BIM), Product Lifecycle Management, sustainability and digital transformation. This approach will help to gain an overarching view of Construction 4.0, BIM and Industry 5.0 and at the same time it will serve to improve the quality of future research on this topic. However, other important technological trends must be taken into account: Edge Computing (EC), digital twins (DT), the Internet of Everything (IoE), big data analytics, collaborative robots (cobots), 6G and blockchain. (Faraji, 2024)

Industry 5.0 continues to evolve and focuses on individual user needs, enabling better interaction between people, machines and advanced technologies. (Aheleroff, 2022)

The primary research objective is to understand resilience measures in the real estate industry, as building technology and the coordination of processes alone can lead to more sustainable use. The first step in this process was to explain the theoretical foundations of Industry 4.0 and Industry 5.0. Moreover, the study will outline the implications of these industries for the construction sector. Sustainability must always be considered as a key perspective, and the currently most significant building materials will be analyzed to demonstrate the sustainability potential of the construction industry. Finally, the insights gained will be summarized, followed by an outlook from the research perspective.

IV. RESULTS AND DISCUSSION

The results of this study highlight the significant impact of integrating Industry 4.0 and Industry 5.0 technologies into the construction and real estate industry, focusing on their potential to improve efficiency, enhance sustainability and address new risks such as climate change. This section presents the results of the analysis and discusses their implications for the industry, particularly in terms of resilience, technological advances and sustainability.

A key finding of this study is that Industry 4.0 technologies – such as big data, artificial intelligence (AI), building information modeling (BIM) and the Internet of Things (IoT) – play a significant role in improving construction processes. These technologies offer a number of benefits to the construction industry, including improved project planning, more efficient resource management and improved decision-making capabilities. Industry 4.0 enables the use of big data analytics to collect and analyze large data sets, climate-related risks and consumer behavior. Therefore, it enables stakeholders to make decisions regarding project planning, risk management and investment strategies. In addition, AI's predictive capabilities in forecasting market trends and identifying emerging risks have been shown to be of great value when it comes to understanding and managing uncertainty in the real estate market. AI can help anticipate fluctuations in property values, insurance costs and environmental risks, enabling more proactive risk management strategies. The integration of BIM is an important finding of this study. BIM facilitates coordination between stakeholders by providing a digital representation of the physical and functional characteristics of a building. This leads to more efficient project delivery, reduces the risk of errors and improves the sustainability of buildings. Through the use of BIM, real estate projects can achieve greater energy efficiency, resource optimization, and a reduction in construction waste. The ability to simulate building performance before construction begins allows for better planning and a more accurate assessment of the environmental impact of each project.

On the other hand, Industry 5.0 takes these advancements a step further by emphasizing the role of human-machine collaboration. This approach fosters a more integrated and collaborative environment, where human creativity and decision-making are combined with the power of automation and advanced technology. The human-centered approach of Industry 5.0 is particularly relevant in the context of real estate and construction, where skilled labor and expertise remain essential. This integration of human knowledge with technological capabilities allows for the creation of more sustainable and adaptive building solutions.

Despite these promising advancements, the study also identified significant challenges that the construction and real estate industries must overcome. One of the key barriers to implementing Industry 4.0 and Industry 5.0 technologies on a large scale is the high cost associated with their adoption. Small and medium-sized enterprises (SMEs) often face difficulties in accessing the necessary capital to invest in these advanced technologies. This creates a digital divide within the real estate industry: large companies are better positioned and can therefore benefit more from technological innovations, while smaller companies are at a disadvantage. Overcoming this challenge will require the development of affordable solutions, as well as policies that promote access to technology for all industry players.

Another challenge highlighted by the results is the need for improved data interoperability and security. The success of technologies such as IoT and Big Data relies on the ability to collect and share data across different

platforms and systems. Which presents an array of challenges, including the lack of a common format relating to data extraction and exchange and increasing concerns regarding data security and privacy. The fixing of the problem will be a major aspect that will characterize the technologies' general applicability as well as realize real benefits for the parties concerned. With respect to sustainability, it has been found that even though the progress towards greener building practices has markedly picked up, there is still much work left to do. The construction industry is still very much in the grip of carbon-intensive construction materials such as concrete. This construction material results in high emissions of carbon dioxide. Though there has been great hand in the recycling and reuse of construction materials, the study believes that there will be a desperate need for the industry to invest in the development of alternative materials that are, at the same time, environmentally friendly and economically sound. Circular economy practices in recycling materials and employing renewable resources need to be explored further.

In conclusion, the potential integration of Industry 4.0 and Industry 5.0 technologies can be a unique opportunity to improve the efficiency and sustainability of the construction and real estate sector while providing resilience." More importantly, developing innovative materials for human use will become critical in defining the future pathway for survival in a digitalized and environmental world.

Technology Benefits and Challenges in Industry 4.0 and 5.0

	Technology	Key Benefits	Challenges
1	Big Data	Data-driven decision-making, market trend	Data interoperability, security
2	AI	Predictive analytics, risk management, trend	High adoption cost for SMEs
3	BIM	Improved project planning, reduced errors, enhanced sustainability	Standardization and widespread adoption
4	IoT	Real-time monitoring, operational efficiency, risk mitigation	Data exchange and privacy concerns
5	Human-Machine-Collaboration	Integrated solutions, enhanced creativity and adaptability	High costs, cultural and organizational shifts needed

Figure 3: Source: authors' own research.

V. CONCLUSION AND OUTLOOK

This research focuses on the transformative potential of Industry 4.0 and Industry 5.0 for the construction and real estate industry. The technologies offer many benefits, optimized workflows, increased efficiency and improved human-machine interaction. However, it also shows that the sector urgently needs a paradigm shift in the face of growing challenges such as climate change, resource scarcity and increasing sustainability requirements. Industry 4.0 has already enabled significant advancements, particularly with technologies like Building Information Modeling (BIM), Big Data, artificial intelligence (AI), and the Internet of Things (IoT), which facilitate more precise planning and execution of construction projects. These technologies not only help to utilize resources more efficiently and reduce costs but also improve sustainability and resource conservation in the construction industry. Industry 5.0 builds upon these advances by placing greater emphasis on human-centered processes, while simultaneously addressing social and ecological aspects. The combination of technological and social considerations offers the construction industry the opportunity to develop resilient and sustainable solutions.

Despite the promising prospects, several challenges remain that hinder the broader implementation of Industry 4.0 and 5.0. A central issue is the continued reliance on traditional building materials such as concrete, whose production remains a significant source of CO_2 emissions. Although recycling concrete and other materials is a promising approach, it is insufficient on its own to significantly reduce the environmental impact. There is an urgent need to develop alternative building materials that are both ecologically sustainable and economically viable. Further barriers exist in data usage and system interoperability. Technologies like IoT and Big Data generate vast amounts of data, the analysis of which could provide valuable insights. However, standardized data formats and adequate data security measures are often lacking, which limits the potential of these technologies. Additionally, especially small and medium-sized enterprises (SMEs) often lack the financial resources to invest in the necessary infrastructure, which could widen the digital divide within the industry.

The social dimension must also not be overlooked. Industry 5.0 aims to integrate humans more deeply into technological processes. This requires a fundamental shift in work organization and the development of new training concepts to ensure that human-machine collaboration is optimized. A key aspect of this transformation is

the adaptation of work culture and the training of skilled workers to ensure the successful implementation of Industry 5.0 technologies in the construction industry.

Looking ahead, two developments are crucial for the future of the sector: First, the increased use of sustainable building materials, and second, the greater application of new technologies to optimize the construction process. This includes a greater integration of renewable energy sources into construction projects, the development of energy-efficient buildings, and the use of AI to predict material needs accurately and optimize construction processes. Real-time data analytics can help identify potential problems in a timely manner and make project planning and implementation more efficient. Second, collaboration between the various stakeholders is crucial to advance both digitalization and sustainable development. Common platforms and standardized interfaces can promote the exchange of data and best practices. Research on Industry 5.0 in the construction sector is still at an early stage. Future studies should focus more on the practical applications of these technologies that go beyond the technological dimensions and include social and economic aspects. Empirical research is needed to analyze the impact of Industry 5.0 on the construction process and sustainable development, thereby solidifying the theoretical considerations. In summary, Industry 4.0 and 5.0 offer the real estate industry extensive opportunities, but also come with significant challenges. Integration into construction processes, combined with a stronger focus on sustainability, is key to future-proofing the industry. With targeted research and consistent investment in technology and sustainability, the construction industry can play a critical role in the transition to a more sustainable and resilient future.

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VII. ACKNOWLEDGMENT