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Closing the Affordable Housing Gap: Identifying the Barriers Hindering the Sustainable Design and Construction of Affordable Homes

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Abstract: Despite the commitment of the United Nations (UN) to provide everyone with equal access to basic services, the construction sector still fails to reach the production capacity and quality standards which are needed to meet the fast-growing demand for affordable homes. Whilst innovation measures are urgently needed to address the existing inefficiencies, the identification and development of the most appropriate solutions require a comprehensive understanding of the barriers obstructing the design and construction phase of affordable housing. To identify such barriers, an exploratory data mining analysis was conducted in which agglomerative hierarchical clustering made it possible to gather latent knowledge from 3566 text-based research outputs sourced from the Web of Science and Scopus. The analysis captured 83 supply-side barriers which impact the efficiency of the value chain for affordable housing provision. Of these barriers, 18 affected the design and construction phase, and after grouping them by thematic area, seven key matters of concern were identified: (1) design (not) for all, (2) homogeneity of provision, (3) unhealthy living environment, (4) inadequate construction project management, (5) environmental unsustainability, (6) placemaking, and (7) inadequate technical knowledge and skillsets. The insights which resulted from the analysis were seen to support evidence-informed decision making across the affordable housing sector. The findings suggest that fixing the inefficiencies of the affordable housing provision system will require UN Member States to accelerate the transition towards a fully sustainable design and construction process. This transition should prioritize a more inclusive and socially sensitive approach to the design and construction of affordable homes, capitalizing on the benefits of greater user involvement. In addition, transformative actions which seek to deliver more resource-efficient and environmentally friendly homes should be promoted, as well as new investments in the training and upskilling of construction professionals.

Keywords: sustainable development; affordable housing; value chain; text data mining; agglomerative hierarchical clustering; barriers; design and construction

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1. Introduction

Mainstreaming sustainable urban development is a key commitment of the New Urban Agenda which all Member States of the United Nations (UN) agreed to adopt in 2016 [1]. Meeting this ambitious target requires urban environments across the world to undertake system-wide transformations leading to structural changes in the configuration of their infrastructure and related processes [2,3]. These changes are expected to introduce innovative measures for improving the sustainability of existing modes of production, distribution, and consumption of social goods and services within urban environments, creating the conditions for more sustainable urban futures [4,5].

As we strive to create cities in which no one is discriminated against and where everyone is provided with equal access to basic services [6], a global commitment to closing the fast-growing gap between the supply and demand for affordable housing is evident [7].

According to the UN's definition, affordable housing is "housing which is adequate in quality and location and does not cost so much that it prohibits its occupants from meeting other basic living costs or threatens their enjoyment of basic human rights" [8]. After analyzing the income and housing statistics related to approximately 2400 cities with a population exceeding 200,000 inhabitants, the McKinsey Global Institute estimated that the global share of the world population struggling to secure quality housing in 2014 was composed of 330 million urban households. The findings of the analysis also suggest this gap is growing wider. For example, if current trends in urban migration and income growth persist, by 2025, 106 million additional low-income households shall be forced to either live in substandard housing or be financially overstretched by housing costs [9].

This massive global challenge is putting pressure on the value chain for affordable homes, whose inefficiency is exacerbating socio-economic inequalities by limiting affordable housing provision. Effective measures for fixing the existing system are urgently needed. However, a comprehensive understanding of the main barriers to the supply of affordable housing is required in order to decide what alternative arrangements should be considered in responding to the UN's call for a more effective provision of affordable housing solutions, in particular those barriers which are affecting the design and construction stage. The housing construction industry plays a central role in the fight against the social and economic distortions which the acute shortage of affordable housing generates. Despite the UN requesting that more reasonably priced homes be provided, building work continually fails to reach the production capacity and to offer the quality standards, which are needed to meet both current and future demand.

This paper seeks to trigger innovation in the affordable housing sector by making key stakeholders in the construction industry aware of such barriers, which are mapped out by conducting a text data mining analysis of 3566 academic publications. To present the findings of this investigation, the paper has been organized in four main sections. The first section presents the background information and rationale of this study, making it possible to set out the numbers behind the affordable housing crisis, present the configuration of the value chain for affordable homes, and point out the lack of wide-ranging investigations providing a comprehensive understanding of its main inefficiencies. The initial section of the paper also offers an explanation of how text data mining can help overcome such a relevant knowledge gap, and it is followed by a discussion of the methodology used to conduct the data mining analysis. This second section details how the barriers obstructing affordable housing design and construction were mapped through uncovering the hidden relationships linking the large amount of data extracted from the textual material. In the third section, such barriers are subsequently discussed in the framework of the available literature on affordable housing. The paper concludes with a reflection on the theoretical and practical implications of the findings. This last section also discusses the limitations of the study and suggests future research opportunities.

2. Background Knowledge and Rationale

By combining statistics on housing affordability across the world, this first section of the paper begins with a description of the magnitude of the global crisis which is impacting the affordable housing sector. These statistics demonstrate that tackling this crisis requires improving process performance in the affordable housing value chain. The section continues with a presentation of the configuration of the value chain for affordable homes. Attention is focused on the supply side of the value chain and the factors hindering its effective functioning. This activity made it possible to highlight the lack of a comprehensive understanding of the barriers to affordable housing design and construction, a knowledge gap which this investigation seeks to fill by using text data mining. The discussion concludes by focusing on how data mining techniques have changed content analytics, making it possible to detect hidden patterns and trends from large datasets by way of statistical and mathematical models, assisted with the artificial

intelligence of machine learning techniques. This last section also provides insight into the sequence of activities structuring text mining analyses.

2.1. The Affordable Housing Challenge

Affordable housing provision is a top policy concern in many countries across the world. Low-income households, especially younger residents, tend to spend most of their disposable income on housing costs, which have increased faster than overall inflation since 1996 [10]. This significant housing cost burden is affecting a growing share of the world's population, and to tackle such a complex issue, governments are introducing either nationwide or geographically targeted affordable housing programmes [11]. These initiatives are implemented to provide subsidized dwellings to those social groups whose housing needs cannot be meet by the market [12–14]. Despite government intervention, the current provision of sustainable affordable housing services is still failing to satisfy the demand of low-income populations.

An overview of the statistics on housing affordability released by the European Union in 2017 shows that across the 28 European Member States, 15.7% of the population lives in overcrowded dwellings due to limited financial capacity and 4% suffers from severe housing deprivation. The estimates also show that the percentage of tenants spending a minimum of 40% of their overall income on housing costs is approximately 30% in Belgium, the Czech Republic, Estonia, Italy, Luxemburg, Hungary, the Netherlands, and Portugal and between 38% and 84% in Bulgaria, Croatia, Greece, Lithuania, Romania, Spain, and the United Kingdom. Overall, these figures lead to an average of 26.3% of the European population (These statistics on housing affordability are provided by Eurostat. Online data codes: ilc_lvho01 (Distribution of population by dwelling type, 2017); ilc_lvho02 (Distribution of population by tenure status, 2017); ilc_lvho05a (Overcrowding rate, 2017); ilc_mdho06a (Severe housing deprivation, 2016 and 2017); ilc_lvho07c and ilc_lvho07a (Housing cost overburden rate by tenure status, 2017)).

The growing financial burden affecting European households is also surfacing in the UK's housing sector, where it has grown in parallel with years of under-supply. To face this low production capacity and keep up with population growth, a radical country-wide reform of the housing market has been proposed which aims to bring between 240,000 and 340,000 new homes per year [15]. However, in this reform, affordability has remained a rather neglected issue [16]. As a result, the majority of local authorities are still not able to cope with the expectations of an increasing demand for affordable housing, because the new additions to dwelling stocks are not genuinely affordable to low-to-middle-income residents [17]. The provision of affordable housing in England remains limited, and in quantifying the demand for affordable housing over a 20-year period, research by the housing and homelessness charity Shelter (a UK-based charity which provides citizens and public authorities in England and Scotland with expert information, support services, and legal advice in order to help them deal with bad housing or homelessness and also conducts independent research aiming to improve the current understanding of the UK housing crisis) has recommended that an additional 3.1 million dwellings will be required within this timeframe [18].

Statistics on affordable housing provision demonstrate that Scotland is affected by the same negative trend. The report Affordable Housing Need in Scotland, which Shelter, the Chartered Institute of Housing Scotland, and the Scottish Federation of Housing Associations jointly commissioned in 2015, showed that housing in Scotland has become increasingly unaffordable for a large share of the population and the national housing programmes are lagging behind, delivering only half of the estimated requirement. The research suggested that Scotland should deliver up to 60,000 dwellings over a 5 year period in order to meet the demand of its population for affordable homes [19]. The current Scottish government responded to this recommendation by setting a target to build at least 50,000 new affordable homes by 2021 [20].

Research conducted by the federal government of the United States finds that acute housing issues are on the rise in the country. Survey data collected in 2015 show that the number of renters with worst-case housing needs have increased from 5.91 million households in 2011 to 8.3 million in 2015. Worst-case needs are low-income renters who live in severely inadequate conditions or need to spend more than 50% of their overall income for rent expenses, without receiving housing assistance from the central government, or both. In addition, the data expose that of those low-income renters, only 50% have been given access to affordable housing units [21]. These figures demonstrate that public housing policies in the United States are not sufficiently effective in satisfying the needs of its low-income residents for affordable housing solutions [22–24].

Despite their significance, these statistics serve to represent only a fraction of a broader landscape because the shortage of affordable homes is a phenomenon which has spread globally. In addition to European countries and the United States, a lack of affordable housing provision has also been reported in Africa [25–27], Australia [28], Canada [29], China [14,30–34], Iran [35], Japan [9], Malaysia [36–38], Mexico [39], Mongolia [40], Pakistan [41], Papua New Guinea [42], Tanzania [43–45], and the United Arab Emirates [46].

2.2. The Value Chain for Affordable Housing Supply

Unequivocal evidence has been offered which demonstrates that the affordable housing gap is enormous and represents a global issue affecting urbanized areas in both advanced and developing economies [8,47]. In addition, with affordable housing needs remaining unmet, the body of evidence currently available also tends to suggest that the global value chain for affordable homes is affected by inefficiencies which are in turn damaging the performance of the provision system. In the light of these developments, the ambition of the UN [6] to ensure access for all to adequate, safe, and affordable housing by 2030 seems at risk, and mapping the existing inefficiencies is key to informing stakeholders within the value chain about the means available to manage this risk and tailor mitigation strategies [48].

"Value chain" is a term used to describe the network of closely interrelated actors whose collaborative action and relationships make it possible to develop products for a specific consumer [49–52]. In the framework of this study, such products are housing assets for low-income populations. When looking at value chains in the construction sector, a marked tendency for waste and inefficiency is exposed, which clearly demonstrates the potential for logistical optimization [53]. Many studies have been conducted which attempt to identify the challenges hindering the supply side of construction value chains and to propose innovative means for changing the practice. For example, challenges have been discussed in relation to fostering collaborative working [54–56], improving workflow sequencing and project management [57,58], introducing modern construction methods [59,60], embracing the full potential of IT-based technologies [61], implementing health and safety reforms [62], implementing corporate social responsibility practices [63], and embedding environmental sustainability principles in building design and construction [64–67], such as reusing recycled building materials [68,69], minimizing construction waste [70], and adopting green building technologies [71,72].

Despite a significant interest in capturing the inefficiencies of construction supply chains, no wide-ranging investigations have been conducted yet which offer a holistic understanding of the main sector-specific barriers which affect affordable housing design and construction. Only a few scientific studies can be identified which share an interest in understanding the barriers to affordable housing provision, but they are somewhat narrow, especially in terms of the knowledge which they offer. These studies rely on single case study analyses focusing on individual issues instead of providing a comprehensive examination of the challenges which the sector is facing [43,73–76].

This paper aims to widen the scope of the investigation and to offer a broader picture by building on research on housing affordability conducted by the World Economic Forum, which recommends adopting a value chain approach [77]. This approach requires mapping

the challenges to affordable housing onto the supply side of the affordable housing value chain, which can be broken down into six value-adding activities (see Figure 1). The process of delivering affordable housing starts with the development of national housing policy settings, in which central governments define the required levels of affordable housing provision, as well as the supporting schemes and programmes which are expected to help the country deliver on the expected targets [78,79]. The national policy guides the network of stakeholders operating in the affordable housing value chain, and its directions inform the urban planning systems which local public authorities shape to coordinate affordable housing practice in cities and regions [80]. In accordance with national and local land use regulations, local public authorities are also required to collaborate with private sector actors in order to assemble and allocate suitable land for affordable housing developments [81–83]. After completing the land assembly process, utility companies and public service providers create the public infrastructure assets for community development which are essential in increasing affordable housing provision. Examples of public infrastructure assets include utility services, transport infrastructure, schools, and open spaces, as well as community, health, and leisure services [84,85]. Housing developers, together with their subcontractors, are then called to organize and execute the design and construction phase of affordable dwellings, which are allocated, managed, and maintained by independent, not-for-profit organizations which provide homes for people in housing need. These organizations generally belong to the housing association sector [86,87].

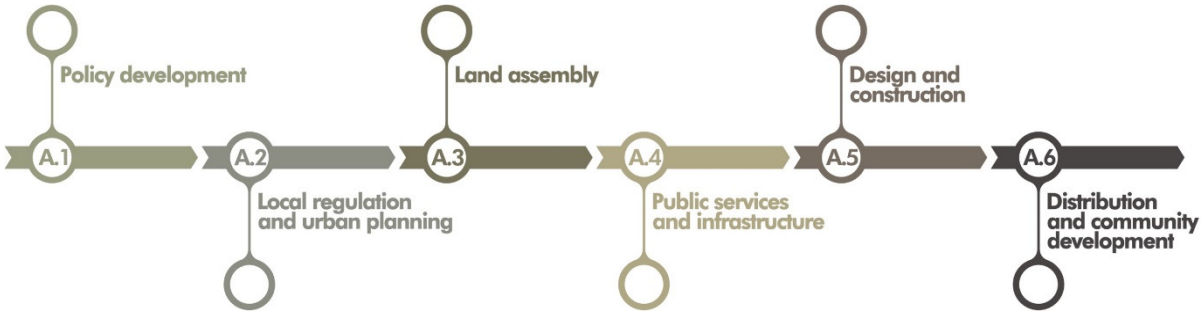

Figure 1. The supply side of the affordable housing value chain.

2.3. Content Analysis with Text Mining

Text mining is the new frontier of content analysis [88] and offers advanced techniques for intelligent data analytics, in which algorithms and statistical models make it possible to extract previously unknown and potentially useful knowledge from large-scale, text-based databases and repositories [89,90]. Text mining covers a broad range of techniques [91], and some of the most commonly used include clustering [88], association rule discovery [92], sequential patterns [93,94], anomaly detection [95–97], regression [98,99], and segmentation [100,101]. The selection of a technique depends upon the reason for conducting the text mining analysis, which can be either exploratory or predictive. Exploratory data mining serves to explore a phenomenon and provide an understanding of its status. In contrast, predictive mining uses already existing information to forecast future events or trends [102].

Usage scenarios are many, and they all demonstrate that text mining techniques can be applied in any knowledge domain to facilitate the acquisition of hidden knowledge which can inform decision making [103,104]. For example, text mining has proven effective when applied for improving sales forecasting systems [105–107], supporting customer acquisition and retention through behaviour analysis [108–110], making scientific discovery more efficient [111,112], monitoring and predicting food quality and safety [113–115], predicting criminal incidents [116], and assisting in talent identification and human resource management [117,118]. In addition, advances in the construction sector suggests data mining is boosting building performance improvement by offering the means to detect or forecast operation deficiencies [119–123].

In exposing a large amount of different text mining techniques which are deployed as a means of achieving different objectives, these examples substantiate the flexibility of the text mining approach to knowledge discovery. In addition, they provide insight into the sequence of activities framing the text mining process, of which research by Aggarwal and Zhai gives a detailed overview [124]. Text data mining projects begin with an in-depth understanding of the subject matter under investigation and the subsequent formulation of a problem for which data mining is needed. Clarifying the problem, which is then redefined into a text mining objective, helps select the data sources to use in the analytical process in order to overcome the identified knowledge gap [125]. These three initial tasks are then followed by data collection and a data preprocessing stage, which starts with data cleaning and concludes with data reduction and transformation operations [126]. After being identified, the data sources are checked, and textual data found to be irrelevant are removed. Data cleaning is particularly recommended when heterogeneous data sources are to be integrated and ensures the knowledge discovery process is not affected by data quality problems, as this can lead to misleading findings [127–129]. Subsequently, the textual data are consolidated into data mining formats by performing a set of tasks which generally fall under the broad categories of reduction, smoothing, normalization, tokenization, lemmatization, aggregation, and stop-word removal [130]. These tasks are conducted to improve the feasibility and accuracy of the data processing phase [124]. The text mining project continues with the following activities: choosing the text mining techniques and algorithm which best align with the objective of the analysis, running the data mining analysis, interpreting the results of the knowledge discovery process, and performing visual data exploration [131].

3. Methodology

Text-based research outputs are "an important information source for decision support tasks" [132] (p. 693), and gathering latent knowledge from large bodies of academic literature has already proven effective in text mining, regardless of the usage scenario. HanChen et al. used the full texts of more than 8000 research articles as input data for mapping the academic concerns related to the Three Gorges Project, which made it possible to build one of the world's largest and most powerful hydroelectric gravity dam [132]. The text mining procedure designed by Yang et al. allows reviewing solar irradiance and photovoltaic power forecasting by collecting information from 1249 academic publications [133]. By combining the text mining of scholarly publications and clinical textual data, Jeong et al. [134] and Zhao and Weng [135] extracted anti-cancer drug research trends and developed a model for predicting pancreatic cancer, respectively.

Building on the successful results of this approach to text analytics, this study mapped the main barriers to the design and construction of affordable housing by conducting an exploratory text data mining analysis of 3566 academic publications. This large-scale collection of scientific documents represents the peer-reviewed literature focusing on affordable housing supply published between 2013 and 2017. The literature was retrieved from the combined results of two complementary keyword searches conducted in the Web of Science and Scopus, two of the most comprehensive and reliable databases indexing academic literature (the search query was framed as follows: TITLE-ABS-KEY/TOPIC ("affordable home*" OR "affordable hous*" OR "affordable construction*" OR "social hous*" OR "public hous*") AND PUBYEAR > 2012 AND PUBYEAR < 2018). [136–138]. This search strategy made it possible to avoid the limitations associated with the use of a single database [139–141], while strengthening the interdisciplinary coverage of affordable housing literature, which was sourced from different scientific fields [142].

The results of the two searches were merged into a single dataset and examined thoroughly to detect and delete duplicate entries. The full texts of the remaining documents were subsequently downloaded and converted to fully editable Rich Text Format (RTF) objects, ready for the data cleaning and preprocessing stages. All the sections of the full texts containing irrelevant textual information were manually removed. This included headers,

footers, in-text citations, references, and details concerning authors and their affiliations. The collection of the RTF files was then uploaded onto the qualitative data analysis software QDA Miner (version 5.0.29), whose deployment made it possible to (1) reduce the high-dimensional setting of the documents; (2) semi-automate the lemmatization, tokenization, and stop-word removal process; and (3) process the text mining. The last two activities were performed by using WordStat (version 8.0.21), an add-on application of QDA Miner which is specifically designed for text mining.

The number of dimensions characterizing a set of documents is equal to the overall number of unique terms they contain. In this context, the terms are considered as variables [143,144]. Applying dimensionality reduction techniques maximizes text mining performance and accuracy by removing words which do not provide information relevant to the objective of the analysis and which generate noise [145]. The reduction process was conducted by using text tagging, a dictionary-based term selection method which allows automatically identifying the most subject-relevant textual entities populating the source documents [146]. Considering that this study aimed to map existing barriers to affordable housing design and construction, a consent analysis dictionary was built with 453 synonyms for "barrier" and cognitive-related words which denote the same concept. (In the framework of this study, the term "barrier" is defined as any condition which makes it difficult to make progress or to achieve an objective.) These alternative words were found by mining the web [147] and the online lexical database WordNet [148]. QDA Miner's keyword retrieval function was then launched to tag all the paragraphs in which at least one of the terms included in the dictionary was included.

The text mining analysis was conducted in WordStat by using the coded segments singled out as part of the dimension reduction process. The terms with the highest co-occurrence (the minimum cooccurrence threshold was set to 350 cases, which corresponds to 10% of the source literature and made it possible to extract 1000 subject-relevant keywords) were extracted and organized in a similarity matrix [149]. Agglomerative hierarchical clustering was then used to transform the similarity matrix into a dendrogram, a tree diagram showing how terms are arranged in nested clusters combined in a hierarchical manner [88,150,151]. Compared to standard clustering algorithms, hierarchical clustering algorithms are more successful in uncovering modularity [152], and depending upon the technique applied to calculate the inter-cluster distance, they are based on four types of widely used distance measures: single linkage, complete linkage, centroid linkage, and average linkage [153,154]. In the framework of this study, the average-linkage distance was selected because it is less sensitive to outliers [149,155]. Therefore, the proximity between two clusters was calculated by considering the average proximity between the textual data objects (p) belonging to each cluster (c) [156]. The average-linkage clustering algorithm (d_{ave}) is defined below in Equation (1):

$$d_{ave}(C_i, C_j) = \frac{1}{(n_i n_j)} \sum p \in C_i, \sum p' \in C_j ||p - p'|| \quad (1)$$

where n_i and n_j are the number of words included in clusters C_i and C_j, respectively [154].

During the clustering process, the cluster assignment of all textual data objects was determined by assessing the extent to which they are related. The within-cluster distance between objects was calculated by applying the Jaccard coefficient [157], which evaluates the overlap between the two terms (S_x and S_y) divided by the total size of the term, is presented as follows in Equation (2):

$$\text{Jaccard}(S_x, S_y) = \frac{|S_x \cap S_y|}{|S_x \cup S_y|} \quad (2)$$

where S_x and S_y are two sets of terms in a pair of clusters [158].

After completing the hierarchical clustering procedure, the groups of keywords belonging to each cluster were analyzed together with their contextual data, placing them in the larger picture. WordStat's Keyword-In-Context feature was applied to assist the examination. This activity was instrumental in observing the keywords within the coded segments and capturing the broader understanding needed to uncover the barriers affecting affordable housing supply which their interrelation reports on. During this exploratory process, each barrier was assigned a code and expressed in the form of a challenge statement to provide a general description of its significance within the affordable housing provision system. The statements were then analyzed to detect and merge duplicate barriers resulting from two or more clusters reporting on the same issue but by using different sets of keywords. Finally, all the barriers were assigned to the section or sections of the value chain in which they were generated.

4. Analysis

The text mining analysis exposed 112 clusters of keywords, from which 83 barriers obstructing affordable housing provision were extracted. Their breakdown by value-adding activity is presented in Figure 2. Four of these items were considered as systemic barriers because they relate to all the value-adding activities, as opposed to specific phases of the supply process. Appendix A links the barriers to their codes and challenge statements, setting out the inefficiencies which need to be addressed to improve affordable housing supply.

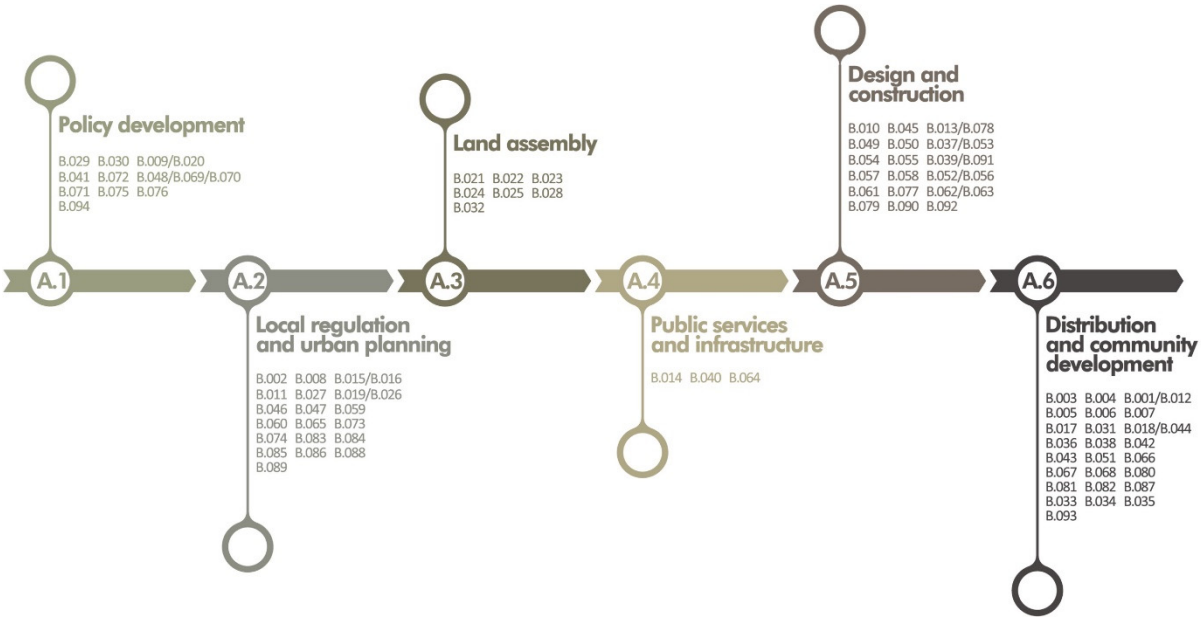

Figure 2. The barriers affecting the affordable housing provision system.

This section of the paper focuses on the 18 barriers affecting the design and construction phase of affordable housing (value-adding activity 5). After grouping these barriers by thematic area, seven key matters of concern were identified, which are presented in the framework of the available scientific literature on affordable housing, as shown in Figure 3. The seven key matters of concern (MoCs) were as follows: (1) design (not) for all, (2) homogeneity of provision, (3) unhealthy living environment, (4) inadequate construction project management, (5) environmental unsustainability, (6) placemaking, and (7) inadequate technical knowledge and skillsets.

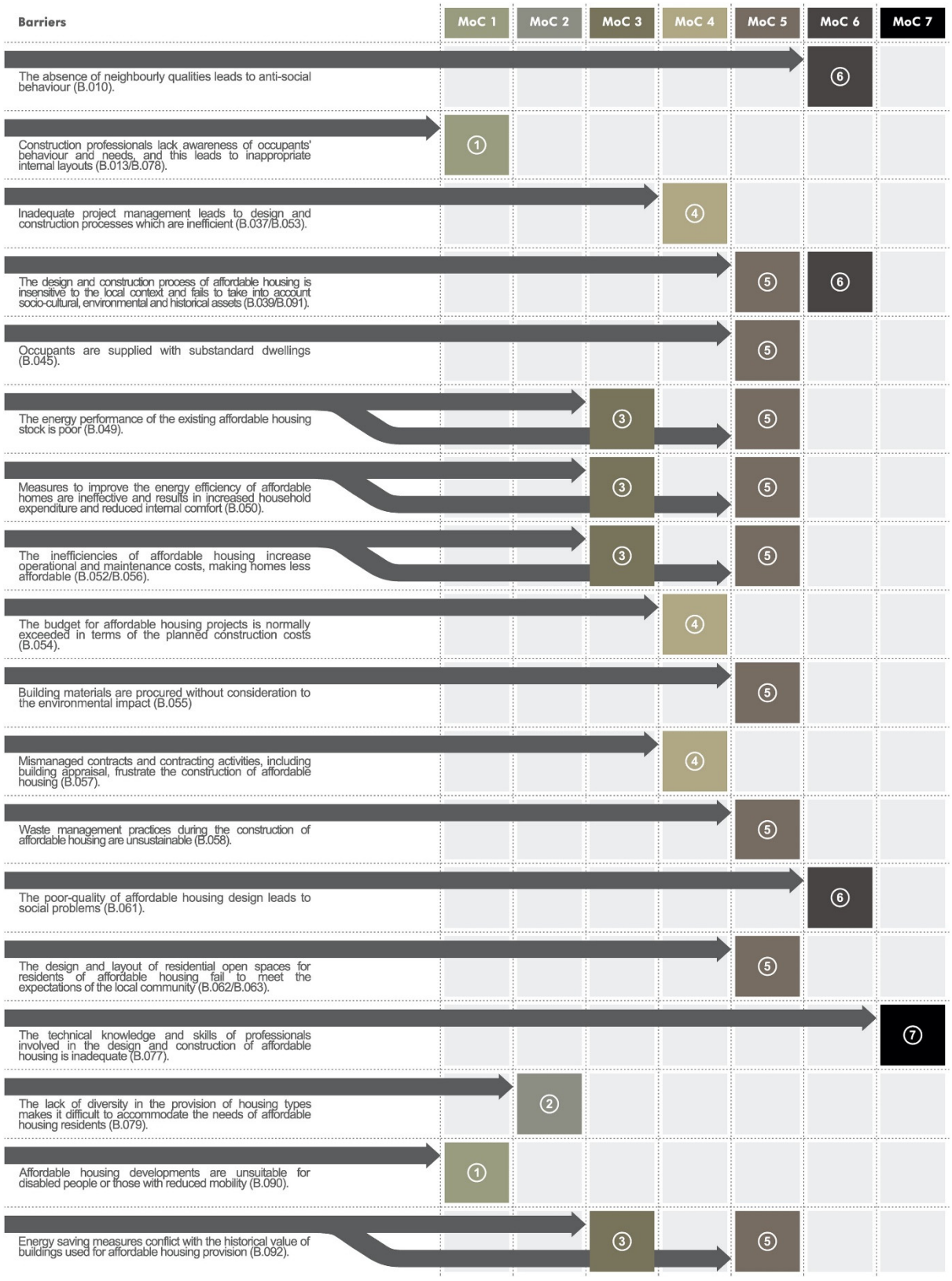

Figure 3. Barriers to affordable housing design and construction by matter of concern (MoC).

4.1. Matter of Concern 1: Design (Not) for All

Poor affordable housing outcomes for low-income groups with high healthcare and support needs are reported internationally. Several studies have displayed a shortage of affordable homes offering features which are relevant to homeless veterans [159], individuals with physical impediments [160–163], and people suffering from psychiatric disabilities [164], cognitive impairments [165], or complex neurological conditions [166]. This suggests that the design of affordable housing solutions is not properly informed by the needs of individuals affected by complex disabilities and that there is a lack of understanding of what design principles can lead to the provision of affordable residential dwellings which are appropriate for these specific populations, who experience the greatest need [167,168].

In addition, individuals with complex disabilities struggle to access affordable homes with a choice of where to live [169]. A significant body of literature has raised concerns about the effect which the design and construction of affordable housing developments has on mix and choice in allocation processes [170]. Social mix has proven to boost the positive social relationships which attenuate the effect of disability on mental health and well-being [171]. However, in affordable residential settings, people with disabilities are typically placed with those with similar needs to improve efficiency, without giving layouts the flexibility required to support inclusion, spatial decentralization, and the preferences of applicants [172].

A more inclusive and adaptive approach to affordable housing design is needed [173] in order to increase the housing choice for individuals with complex disabilities—an approach which must incorporate specialized physical, psychological, and social features into mainstream affordable housing solutions [167,169].

4.2. Matter of Concern 2: Homogeneity of Provision

Addressing the diverse housing needs of low-income groups by offering a mix of affordable housing options is key to fostering sustainable communities [174,175], and this cannot result from a "one-size-fits-all mentality" [176]. A number of studies have attempted to investigate the relationship between diversity and affordability, providing evidence which demonstrates that there is a strong link between these two factors.

Using US metropolitan statistical data, Chakraborty and McMillan explored the role of diversity at the neighbourhood scale and demonstrated that the rate of foreclosure is higher in urban areas where housing diversity is lower [174]. This correlation suggests that the homogeneity of housing stock can increase the relative value of units, generating a lack of affordable housing. Recent studies examining the effects of land use regulations on housing affordability in Australia confirm this trend. After comparing four suburban districts of the metropolitan area of Adelaide, McGreevy observed that the districts in which the land use policies have limited the growth in diversity of their housing stocks are also affected by a relative lack of affordable dwellings [177]. The negative correlation between the number of diverse dwelling types and the relative median house price has also surfaced in the Sydney metropolitan region [178]. As a consequence of this growth in prices, the ownership of housing assets tends to concentrate in the hands of an ageing and shrinking demographic [179].

Offering a diverse housing stock requires governments and stakeholders in the construction sector to better understand the diverse housing needs of heterogeneous residents and use such knowledge to design affordable housing solutions which are tailored to meet their expectations [175]. Affordable housing provision should be diversified in terms of types and tenure, hence providing accommodation options to a broader range of residents and creating a diverse and vibrant neighbourhood.

4.3. Matter of Concern 3: Unhealthy Living Environment

It has been acknowledged that prolonged exposure to poor housing conditions can generate physical and mental disorders, increase the spread of infectious diseases [180], and reduce social well-being [181]. Adequate affordable homes should provide security, protection from domestic injuries, an acceptable level of indoor quality, and shelter from outdoor temperatures, dust, insects, rodents, and noise. Maintaining adequate indoor thermal comfort without compromising housing affordability requires energy-efficient homes. However, a significant body of literature shows that (1) a growing percentage of the existing affordable housing stock has poor energy performance, making homes less affordable, and (2) the data describing the effectiveness of retrofitting practices in the affordable housing sector suggest that the expected benefits are not always achieved and that discrepancies between predicted and actual savings may surface [182–187].

Low energy efficiency and high energy prices increase housing expenses and force a growing number of low-income occupants to live in fuel poverty [188], a long-standing issue generating wider social and health inequalities [189,190]. Low-income households living in fuel poverty cannot afford to keep their dwellings at adequate indoor temperatures. As a result of this failure in achieving thermal efficiency, occupants are not protected from outdoor environmental conditions and are more exposed to dust mites, mould, and fungal spores due to reduced ventilation usage, increased air contamination, and poor hygrothermal conditions [191,192]. In addition to living without the basic level of energy needed to guarantee their well-being, the budget constraints of fuel-poor households also affect their capability to invest in retrofitting interventions for improving the energy efficiency of their substandard homes [182,183,193].

Energy poverty is recognized as a global concern facing the affordable housing sector [194]. According to the estimates released by the Buildings Performance Institute Europe (BPIE) in 2012, 10.8% of the European population was unable to keep indoor environments at a liveable temperature, and the figure increases to 24.4% when the analysis is conducted with low-income groups only [195]. Key results from the censuses conducted by Statistics Canada show that (1) 1 million households are affected by energy poverty, with energy costs which are putting them at risk of becoming homeless, and (2) the low-income population of Ontario has suffered a significant loss in quality of life due to increased expenditure on electricity bills, with the least affluent suddenly having to make choices between rent, heating, lighting, or food [182]. Recent statistics demonstrate that fuel poverty is also affecting 10.8% of the population living in England, a figure which represents approximately 2.5 million households [196].

4.4. Matter of Concern 4: Inadequate Construction Project Management

Inadequate construction project management affects all stages of the affordable housing design and construction phase and is mainly caused by a lack of planning, insufficient coordination, inefficient communication and collaboration practices between project partners, failure to identify and solve problems, and a lack of control over time and cost inputs. The ineffective implementation of project management processes leads to reduced quality of the final products, delays in completion, and increased construction costs, making housing less affordable. The literature reporting on poor project management practices in the housing sector exposes the global dimension of this phenomenon but also demonstrates that it tends to manifest more in emerging economies. Some of the countries in which this phenomenon has been detected include Ethiopia [197,198], Ghana [199], India [200,201], Nigeria [202], Tanzania [43,203,204], and Saudi Arabia [205].

Research investigating affordable housing provision in Africa shows that poor project management is one of the main factors causing the failure of residential construction projects [199]. Due to limited project management skills, many small- and medium-size housing construction companies struggle to deliver affordable homes, in particular when working on large-scale developments and when modern construction techniques are ap-

plied. As a consequence, construction time and costs tend to overrun, and this has frequently led to project failure [25].

Additional factors reducing the project management efficiency of housing developers operating in African countries include political interference, payment delays, bureaucratic hurdles, corruption, poor supervision, a lack of commitment from project leaders, a change in government, escalation of construction costs, a lack of alignment to existing regulations, and poor communication between clients and contractors [197,204,206–208]. Bureaucracy and corruption were also identified as key factors in research conducted by Ram and Needham, who investigated the barriers reducing the capacity of home developers to satisfy the growing demand for affordable dwellings [201]. Deep et al. extended this list by demonstrating that the failure of Indian affordable housing projects can also occur due to contractor-induced delays, which results from poor financial management and a lack of planning and scheduling [200].

4.5. Matter of Concern 5: Environmental Unsustainability

The technical performance of affordable housing developments is often affected by sustainability issues. Sustainable development principles are not always embedded in the design and construction of affordable homes, and when the importance of sustainability requirements is neglected, a number of socio-economic and environmental challenges can surface, which expose the existing "gap between sustainable housing and affordable housing" [209].

A growing share of the existing affordable housing stock is having an adverse impact on the environment due to poor energy efficiency performance. As a consequence, cutting the current energy demand and reducing the greenhouse gas emissions of existing low-income housing developments have become a global priority [210–213], as well as ensuring that future affordable dwellings are built by considering the efficiency standards needed to advance a zero-emission scenario [32,214–216].

Research looking into the affordable housing sector suggests that the environmental deficits of low-income housing developments mainly spring from the selection of sub-standard building materials [172,217]. For example, Heravi and Qaemi demonstrated that affordable housing provision can be inhibited by (1) the resistance of housing developers in accepting new materials, whose adoption could improve the environmental performance of a building over the life cycle, and (2) the preference of the sector for imported rather than local building materials, a choice which leads to increased transportation costs and additional carbon emissions [218]. In addition, research also reports on affordable housing projects where unsustainable construction waste management practices were applied [219].

4.6. Matter of Concern 6: Placemaking

Additional sustainability challenges surface when the design and construction of low-income housing arrangements is not properly "nested within the local context" [220] (p. 148) and its cultural requirements [220–222], or the importance of community spaces for recreation and informal gatherings, is not taken into proper account [176,222,223]. Drawing upon evidence gathered from research into environmental psychology, it is widely acknowledged that the physical characteristics and design of housing for disadvantaged populations can trigger disputes between residents and stimulate anti-social behaviour [223]. In addition, it is also demonstrated that poorly designed residential green spaces, which are disconnected from the social, economic, and physical conditions of the local context, can exacerbate these tensions and instigate a sense of insecurity [224]. Good-quality housing green spaces require accessibility for all, adaptability, inclusiveness, and biodiversity [225]. The presence and use of such natural settings can benefit residents by raising their level of satisfaction and sense of well-being, reducing their concerns about density and the disadvantages generated by overcrowded conditions, and improving the level of social cohesion within the neighbourhood [226,227].

4.7. Matter of Concern 7: Inadequate Technical Knowledge and Skillsets

Identifying housing developers equipped with the technical knowledge and skills needed to sustain the provision of housing for low-income populations is a significant challenge facing the construction sector [176,228–230]. In particular, professionals working in the housing construction industry lack a proper understanding of how modern construction techniques can be adopted in order to improve the quality and efficiency of the design and construction process [60,231,232].

A significant body of evidence suggests that modern construction techniques can offer significant advantages over traditional site-built construction methods, such as improving workflow continuity [233], increasing efficiencies in the use of resources [234–236], minimizing construction waste [237–239], reducing greenhouse gas (GHG) emissions and life cycle energy use [240–243], and reducing both the number of on-site contractors and construction duration [244,245]. While improving the sustainability of the end products, all these aspects contribute to lowering the overall construction costs, making housing more affordable to low-income populations.

For example, in analyzing a set of residential buildings in Hong Kong, Jaillon and Poon showed that off-site construction methods make it possible to obtain an average of approximatively 15% and 16% reduction in construction time and labour requirement, respectively [245]. In addition, timber formwork and concrete works reduced by 74–87% and 51–60%. Research conducted by Central South University and the National University of Singapore confirms the validity of these findings by reporting a potential 5–10% saving of construction costs through the adoption of off-site construction techniques [234]. The analysis shows that these savings result mainly from the higher efficiencies which the industrialized production process of building components can offer, combined with quick on-site assembly, reduced on-site workforce, and increased labour efficiency. The industrialized production process which off-site construction relies on also offers a higher level of predictability, which makes it possible to obtain an improved degree of cost certainty and increased labour efficiency [235,236].

The economic benefits which off-site construction can deliver were also highlighted by Pan and Sidwell [246], Økland et al. [247], and Li et al. [248]. Pan and Sidwell examined the cost performance of 20 medium- to high-rise residential buildings developed by UK housebuilders in which off-site construction solutions were adopted [246]. The findings showed that construction cost savings compared to traditional building techniques range from 11% to 32%. Økland et al. demonstrated that the use of off-site construction technology helps lower construction costs due to the decreased amount of time which is necessary to spend on quality assurance [247]. The factory environment enables the components to be strictly controlled through automated technological systems. This economic benefit was also captured by Li et al. whose critical review of available research demonstrated that better supervision and shortened construction time are some of the most essential advantages of adopting modern construction techniques and the resulting reduced overall construction cost [248].

Modern construction techniques have also proven effective in improving the sustainability of design and construction processes by reducing both construction waste and emissions of carbon dioxide into the atmosphere. Tam et al. reported on the potential for modern construction techniques to reduce waste [237]. Building on the findings of a multi-case study analysis comparing 14 traditional construction projects with 16 off-site construction projects, their study shows that construction waste is minimized up to 84.7% when off-site construction technology is applied. Similarly, while conducting a comprehensive review of the evolution of prefabricated residential building systems in Hong Kong, in both public and private sectors, Jaillon and Poon [238] and Jaillon et al. [249] found a 52% waste reduction level when traditional construction techniques were replaced by an approach based on off-site construction technology. Finally, Gao and Low's 2014 investigation of the T30 Tower Hotel shows several benefits which include magnitude 9 earthquake resistance, low construction cost, high thermal efficiency (leading to low

maintenance cost), and only 1% construction waste generation compared to conventional buildings [239].

By comparing two residential projects, Mao et al. showed that the use of off-site methods can reduce GHG emissions per square metre when compared with conventional construction. The former produced 336 kg/m^2 of GHG emissions and the latter 368 kg/m^2 [241]. According to the study, the largest proportion of GHG emissions is generated from the embodied emissions of building materials, which account for approximately 85% of total emissions. Four elements which positively contribute to reducing emissions are the embodied GHG emissions of building materials, transportation of building materials, resource consumption of equipment and techniques, and transportation of waste and soil, which account for approximately 86%, 18%, 10%, and 0.2% of reduced emissions, respectively.

Finally, research by Hong et al. [250] and Teng et al. [243] has proved that the use of off-site construction methods can reduce building life cycle carbon emissions. Hong et al. compared eight construction projects developed in Sichuan, Shanghai, and Shenzhen [250]. The results of the analysis show that between 4% and 14% of the total energy consumption was saved by using prefabricated components instead of cast-in-place concrete [240]. Teng et al., whose empirical analysis compared 27 prefabricated buildings, captured that "on average, 15.6% of embodied and 3.2% of operational carbon reductions were achieved through prefabrication, as compared with their traditional base cases" [243] (p. 313).

Despite such benefits, research suggests that the lack of qualified construction workers is one of the main factors inhibiting the adoption of more sustainable construction techniques in China [251–255], Australia [256], New Zealand [257] and the United Kingdom [258,259], where an absence of the necessary training programmes has been identified. Arditi et al. suggest that this condition reflects the current engineering and architecture curricula, which tend to focus little on modern construction methods and technologies, whose deployment implies radical changes in the traditional approach to design, fabrication, and construction [260]. This condition leads to insufficiently qualified workers, who lack the appropriate technology and management experience and whose employment can compromise the affordability of dwellings due to the incurrence of severe problems, such as inferior structural performance, delays [261], and construction safety accidents [252], which cause production costs to rise [262].

5. Conclusions

This paper can help key stakeholders in the construction industry identify innovation potential in the affordable housing sector by making them aware of the barriers to the design and construction of affordable homes. These barriers were mapped out by conducting a text data mining analysis of more than 3500 academic publications. Overall, the data mining captured 83 barriers describing the inefficiencies of the current supply side of the value chain for affordable housing provision. Of these barriers, 18 affect the design and construction phase, and after grouping them by generated impact, seven main matters of concern were identified: (1) design (not) for all, (2) homogeneity of provision, (3) unhealthy living environment, (4) inadequate construction project management, (5) environmental unsustainability, (6) placemaking, and (7) inadequate technical knowledge and skillsets.

In analyzing the main barriers to affordable housing design and construction, this paper contributes to evidence-informed decision making in the affordable housing sector. The insight resulting from the analysis is shown to be instrumental in setting development priorities for the affordable housing sector, proposing innovation actions for overcoming inefficiencies, and orienting future research towards relevant strategic questions whose investigation can help boost productivity and improve the quality of affordable housing solutions. Future research should also consider the impact of emerging digital technologies, whose ability to automate and monitor (in real time) the design and construction stage provides a further opportunity to enhance the provision of affordable housing.

The findings of this investigation demonstrate that fixing the inefficiencies of the affordable housing provision system is a global priority and requires a stronger commitment to accelerating the transition to a fully sustainable design and construction process. The current approach to affordable housing design and construction is affected by socio-economic, cultural, and environmental sustainability constraints which are depriving low-income groups from their right to access affordable, safe, and healthy housing solutions. This approach undermines the global commitment set out by UN Member States for closing the gap between the demand and supply of affordable housing and puts this policy at risk.

Evidence was provided which suggests that the acceptance and cost of affordable housing is strongly affected by both the participation of service users in the development process and the diversity in housing options at the neighbourhood scale. This in turn indicates that to optimize design and construction operations in the affordable housing sector, a more inclusive and socially sensitive approach should be encouraged which capitalizes on the benefits of a greater involvement of service users. Engaging with residents during the design process provides an opportunity to acquire a greater understanding of user needs and to offer communities a diverse mix of technically and financially feasible affordable dwellings able to meet the expectations of everyone, in particular the expectations of more vulnerable groups affected by physical and mental conditions, whose views are currently under-represented in the decision-making process informing the design and construction of affordable housing.

The input from residents has also proven effective in avoiding the standardization of design solutions for affordable housing. In the past, retrofitting practices tended to be predicated on unrealistic energy modelling, which failed to account for unforeseen occupant behaviour. As a result, large deviations have surfaced between predicted, and actual, energy performance. Co-creation research demonstrates that profiling household typologies and taking into account occupancy patterns and comfort preferences are key to minimising such discrepancies.

To conclude, addressing the barriers hindering the sustainable design and construction of affordable housing requires the adoption of socially inclusive innovation strategies which are supported by transformative actions that aim to maximise resource efficiency and promote environmental sustainability. An important feature of this transformation is ensuring sufficient investment in the training and upskilling of construction professionals to facilitate the shift from traditional to modern methods of design and construction.

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Appendix A

Table A1. Barriers by value adding activity. A.1: Policy development; A.2: Local Regulation and urban planning; A.3: Land assembly; A.4: Public service and infrastructure; A.5: Design and construction; A.6: Distribution and community development; STR: Structural.

Value-Adding Activity	Barriers	
	Code	**Challenge Statement**
A.6	B.001/B.012	Low-income residents do not have the economic stability necessary to comply with their tenancy agreement over the long term.
A.2	B.002	Local governments are unable to use affordable housing provision as a tool to secure social cohesion.

Table A1. *Cont.*

Value-Adding Activity	Barriers	
	Code	**Challenge Statement**
A.6	B.003	Residents living in affordable accommodation do not feel safe, secure, and supported in their homes.
A.6	B.004	Affordable homes offer inadequate living arrangements because they are poorly maintained.
A.6	B.005	During the refurbishment of affordable housing, social landlords experience difficulties in rehousing residents.
A.6	B.006	Prospective residents experience difficulties in finding temporary accommodation whilst waiting for affordable homes to become available.
A.6	B.007	People living in affordable housing who are affected by health problems do not have sufficient community support.
A.2	B.008	The time and resources needed to apply for planning permission are high and can generate significant delay.
A.1	B.009/B.020	Current national policies fail to address the existing challenges that the affordable housing sector is facing.
A.5	B.010	The absence of neighbourly qualities leads to anti-social behaviour.
A.2	B.011	Local governments are unable to reconcile the provision of affordable housing with environmental sustainability.
A.5	B.013/B.078	Construction professionals lack awareness of occupants' behaviour and needs, and this leads to inappropriate internal layouts.
A.4	B.014	People living in substandard housing are less able to access appropriate health and social care services.
A.2	B.015/B.016	Housing regulations give preferential treatment to traditional families, while limiting access to housing to single parents with children.
A.6	B.017	Women who have experienced domestic violence face difficulties in securing affordable accommodation.
A.6	B.018/B.044	Affordable housing residents default on their mortgage repayments due to high interest rates.
A.2	B.019/B.026	Policies designed to address affordable housing issues are not properly incorporated into local planning regulations and city development strategies.
A.3	B.021	Supply of infill affordable housing developments in existing residential areas is limited due to difficulties in assembling land for construction.
A.3	B.022	Supply of infill affordable housing developments in existing residential areas is limited due to difficulties in securing development finance.
A.3	B.023	Legal and urban planning constraints prevent the development of affordable housing on infill sites.
A.3	B.024	The potential development of affordable housing on infill sites is frustrated by community opposition to higher-density developments.
A.3	B.025	The ability of the local government to supply more land for affordable housing development is limited by weak fiscal capacity.
A.2	B.027	There is a lack of community participation in the planning of affordable housing developments.
A.3	B.028	High land values in urban areas restricts the construction of affordable housing.
A.1	B.029	Affordable housing provision is limited by the lack of guidance from the central government to local authorities.
A.1	B.030	Affordable housing provision is limited by the lack of financial support from the central government to local authorities.
A.6	B.031	Inequalities in service provision relate to the age of tenants.
A.3	B.032	Land use planning practices generate urban and regional disparities in affordable housing provision.
STR	B.033	Insufficient collaboration between service providers and service users fails to support affordable housing provision.
STR	B.034	Insufficient understanding of the critical factors leading to success or failure makes it difficult to manage affordable housing development projects.
STR	B.035	The lack of transparent and consistent communication between public sector agencies and private sector organizations results in the under-provision of affordable housing.

Table A1. *Cont.*

Value-Adding Activity	Barriers	
	Code	**Challenge Statement**
A.6	B.036	Residents lack the basic skills to comply with their tenancy agreement.
A.5	B.037/B.053	Inadequate project management leads to design and construction processes which are inefficient.
A.6	B.038	Affordable housing communities face a multitude of behavioural problems leading to socio-economic challenges.
A.5	B.039/B.091	The design and construction process of affordable housing is insensitive to the local context and fails to take into account socio-cultural, environmental, and historical assets within the community.
A.4	B.040	The provision of essential services and infrastructure fails to meet the needs of affordable housing residents.
A.1	B.041	Demand-side subsidies fail to promote affordable housing.
A.6	B.042	Social landlords transfer increased taxation costs on to their tenants.
A.6	B.043	Social landlords ask prospective tenants to pay several months of rent in advance.
A.5	B.045	Occupants are supplied with substandard dwellings.
A.2	B.046	Overly restrictive zoning and construction regulations limit affordable housing provision.
A.2	B.047	Insufficient local government capacity limits affordable housing provision.
A.1	B.048 /B.069/B.070	There is a lack of financial instruments to support low-income groups in accessing affordable housing services.
A.5	B.049	The energy performance of the existing affordable housing stock is poor.
A.5	B.050	Measures to improve the energy efficiency of affordable homes are ineffective and result in increased household expenditure and reduced internal comfort.
A.6	B.051	Residents' inefficient energy consumption leads to higher household expenditure, impacting their financial independence.
A.5	B.052/B.056	The inefficiencies of affordable housing increase operational and maintenance costs, making homes less affordable.
A.5	B.054	The budget for affordable housing projects is normally exceeded in terms of the planned construction costs.
A.5	B.055	Building materials are procured without consideration to the environmental impact.
A.5	B.057	Mismanaged contracts and contracting activities, including building appraisal, frustrate the construction of affordable housing.
A.5	B.058	Waste management practices during the construction of affordable housing are unsustainable.
A.2	B.059	Poor land use planning frustrates affordable housing provision.
A.2	B.060	Local governments generate bureaucratic problems, which cause affordable housing projects to fail.
A.5	B.061	The poor quality of affordable housing design leads to social problems.
A.5	B.062/B.063	The design and layout of residential open spaces for residents of affordable housing fail to meet the expectations of the local community.
A.4	B.064	The lack of support services restricts low-income residents from gaining access to employment opportunities.
A.2	B.065	Urban planning practices concentrate poverty in specific neighbourhoods, exacerbating problems related to social exclusion.
A.6	B.066	The letting policy of social landlords causes ethnic tensions in the provision of affordable housing.
A.6	B.067	Minority ethnic groups living in affordable housing feel segregated.
A.6	B.068	Affordable housing tenants are unable to relocate or swap properties with other tenants.
A.1	B.071	The lack of tax incentives available to affordable housing providers and subsidies to occupiers result in chronic under-investment within the sector.
A.1	B.072	Inflation renders housing unaffordable.
A.2	B.073	Affordable housing developments are often located in areas where the provision of public transport is limited, resulting in residents experiencing mobility problems.
A.2	B.074	Residents and representatives of the local community are under-represented in the decision-making process.

Table A1. *Cont.*

Value-Adding Activity	Barriers	
	Code	**Challenge Statement**
A.1	B.075	The national government fails to adopt a participatory approach when managing policies relating to affordable housing.
A.1	B.076	The stakeholders invited to co-design affordable housing policies do not have equal decision-making powers, and this generates tensions.
A.5	B.077	The technical knowledge and skills of professionals involved in the design and construction of affordable housing are inadequate.
A.5	B.079	The lack of diversity in the provision of housing types makes it difficult to accommodate the needs of affordable housing residents.
A.6	B.080	Affordable housing developments lack diversity of tenure and socio-economic mix.
A.6	B.081	Drug users in treatment face difficulties in accessing affordable housing.
A.6	B.082	Tenancy frameworks fail to provide sufficient legal protection for occupiers.
A.2	B.083	The legal and regulatory frameworks for the affordable housing sector fail to provide clear assessment rules.
A.2	B.084	The building standards for affordable housing are underdeveloped.
A.2	B.085	The lack of consistency between state, regional, and city plans for affordable housing leads to under-provision.
A.2	B.086	Absence of comprehensive planning documents for affordable housing (such as strategic plans, annual performance plans, and operational plans) leads to the under-performance of the sector.
A.6	B.087	Social landlords do not follow guidelines related to the allocation of affordable housing tenants.
A.2	B.088	Absence of prescribed time frames for the allocation of plots to potential beneficiaries leads to slippages in the supply of affordable housing.
A.2	B.089	Local regulations do not effectively manage the tensions generated by the development of mixed-income communities.
A.5	B.090	Affordable housing developments are unsuitable for people with disabilities or those with reduced mobility.
A.5	B.092	Energy-saving measures conflict with the historical value of buildings used for affordable housing provision.
STR	B.093	The current system used to evaluate affordable housing is unable to assess the effectiveness of provision.
A.1	B.094	The lack of shared equity schemes and other ownership assistance programmes aimed at low-income residents restricts the provision of affordable housing.

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