

A Scientometric Analysis of the Housing Affordability Literature

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Abstract

Interest in the global unaffordable housing crisis is evident in its burgeoning publications. However, systematic review of the literature is limited concerning data visualization and mapping of the knowledge structure and worldwide trend of publications on housing. This study seeks to fill this knowledge gap through a quantitative method – scientometric analysis. To this end, three networking tools – CiteSpace, VOSviewer and Gephi – were employed in analysing 11,981 bibliographic records retrieved from Scopus for two decades (1998 to 2017). The research findings are informative in identifying trends, linkages and gaps in the literature. Besides, they reveal collaboration pattern among countries, academic institutions and publication outlets of housing studies. These have practical implications for policymakers. The findings are indicative of pivotal areas of relatively low research outputs that can be the focus for further research. They are also important for efficient research and development policies for attaining the United Nations Sustainable Development Goals on housing.

Keywords: Public housing; Social housing; Affordable housing; Co-operative housing; Sustainable housing; Housing affordability

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1. Introduction

Housing is one of the key drivers of the socio-economic development of every nation. As such, effective housing supply is among the policies of governments. These policies are often established to ensure housing affordability for all income categories especially among middle- and low-income earners (Chan & Adabre, 2019; Adabre & Chan, 2019). Housing affordability means securing a given standard of housing at a given price or rent which does not impose in the eye of a third party (usually government) an unreasonable burden on households' incomes (Maclennam & Williams, 1990). Various terms have been coined to describe forms of housing that are affordable to middle-and low-income earners or the poor in society. Some of these terms could cover different housing tenures based on the country under consideration. Among the terms for various forms of housing include: affordable housing (which is frequently used in the USA and could be rental and ownership housing); public and social housing (are more strongly linked to rental housing in a European context); cooperative housing (as used in some European countries and ownership of entire building is held in common by homeowners' association) etc. (Czischke & van Bortel, 2018; Malpass & Victory, 2010). Notwithstanding the benefits of ensuring housing affordability and accessibility for socio-economic growth, housing unaffordability crisis remains an intractable situation globally.

Unaffordable housing crisis is a major problem in both developed and developing countries. This is evinced in lack of housing facilities and its effect of increasing formation of slums (i.e. overcrowded and decrepit urban residential facilities that lack adequate infrastructure) (Golubchikov & Badyina, 2012). Thus, aside the housing deficits, some of the existing facilities are not adequate. If left uncontrolled, the housing shortage and its inevitable corollary could even be worst considering the anticipation of the world's population growth from 3.6 billion to 6.3 billion by 2050 (Golubchikov & Badyina, 2012). Based on the worldwide housing crisis, policies have been initiated among international organizations such as the World Bank and the United Nations (UN) to ensure adequate housing (Adabre et al., 2020). For instance, the UN policy goal, Target 11.1 of the Sustainable Development Goal II states: 'By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums' (UN, n.d.). Thus, in addition to ensuring housing affordability, the strive to achieve social and environmental sustainability goals for a holistic sustainable development remains a topical issue in both developed and developing countries. For the realisation of these goals, many empirical studies have been conducted on the various facets of sustainable housing. Essentially, the plethora of studies increases the knowledge base for policy formation. Yet more importantly, the impact of extant literature for policy development could be augmented through a systematic review of the burgeoning publications on housing. Systematic

reviews are essential for evaluating existing knowledge towards determining what is uncovered and for pointing out significant research areas that are overlooked and need further research to enhance existing policies.

Previous systematic reviews have focused on some aspects of the housing literature. [Nguyen \(2005\)](#) conducted a review study concerning the effects of affordable housing on the prices of neighbouring properties. It was concluded, after the analysis of 17 studies, that the extent to which property values are lowered depends on a variety of factors, namely, design and management of affordable housing; compatibility between affordable housing and host neighbourhood and concentration of affordable housing. On a different aspect of the housing literature, [Adabre & Chan \(2018\)](#) conducted a review of 34 articles to determine the critical success criteria for sustainability attainment in affordable housing. Furthermore, a review study by [McCabe et al. \(2018\)](#) focused on 67 studies for identifying the success factors, barriers and motivations for the application of energy technologies in social housing. Moreover, [Anderson et al. \(2003\)](#) reviewed two housing programs which aimed to provide affordable housing as well as reduce segregation of low-income families. Their review findings were based on 23 articles and reports. In a different study, after analysing three main housing policies, [Sun & Liu \(2009\)](#) concluded that the implementation of housing mix policy disperses poverty concentration; enhances security of neighbourhood and satisfaction and diversity of neighbourhood. Yet, its implementation has no evident effect on adult's employment and income. On environmental sustainability, reviews on barriers and drivers for green building in housing have been conducted by [Darko & Chan \(2017\)](#) and [Darko et al. \(2017\)](#), respectively.

Although these reviews contribute immensely to the literature on housing affordability and other sustainability goals, they were manually conducted with relatively small sample size of articles. Small sample sizes of articles for a review study could limit the statistical power and affect the generalization of the findings ([Nguyen, 2005](#)). In addition, manual reviews explore specific and limited aspects, but they do not present an eclectic review of extant literature. This could lead to the risk of overlooking relevant research questions that require research and practical improvement ([Hosseini et al., 2018](#)). Furthermore, according to [Yalcinkaya and Singh \(2015\)](#) and [Darko et al. \(2019\)](#), manual reviews could be biased due to subjectivity. Moreover, review studies are limited concerning the analysis and visualization of the different and vast scopes of the housing literature. Based on these stated caveats in the method of previous reviews, the present study adopts a quantitative method – scientometric analysis – with the aim of providing some insights into scientific data networking and visualization of existing studies on housing affordability.

Scientometric analysis provides an objective approach for reviewing the broad scopes of the prolific housing research articles published in the past two decades, i.e. 1998-2017 (inclusive). Using CiteSpace, VOSviewer and Gephi, the analysis provides networks of keywords co-occurrence, influential keywords that attracted much interest within certain periods (burst analysis) and the dominant categorizations of the housing affordability literature with regard to keywords (cluster analysis). Essentially, keyword co-occurrence analysis, keyword burst analysis and keyword cluster analysis were conducted to explore central topics, emerging trends, intellectual structure and knowledge gaps in the housing affordability literature. The knowledge gaps could then inform local and national policy formation or research direction for sustainable housing (Zhao et al., 2019). Moreover, network analyses of countries and institutions were conducted which depict collaboration trend and pattern among the most productive countries, institutions and publication outlets / journals in the literature. The study offers industrial experts and academics a comprehensive review in addition to pointing out future research directions. The research findings have practical implications for countries, institutions (i.e. universities) and editors of journals on improving knowledge creation. Such findings are relevant for resource allocation on research and development (R&D) policies on collaboration among countries and academic institutions (i.e. universities). R&D policies on collaboration could enhance all-inclusive housing policies for achieving the UN Sustainable Development Goals by 2030.

2. Research Methodology

2.1 Selection of Method

In a broader perspective, “science mapping” was adopted as the research method for this study. This method was chosen because of its capabilities in spatially representing interrelationship and dynamics among disciplines, fields, individual documents and authors of scientific research (Börner et al., 2003; Morris and Van der Veer Martens, 2008). It is also used for discovering key elements that have been less studied within a research interest. Science mapping consists of three overlapping techniques, namely, informetrics, bibliometric analysis and scientometric analysis (Hosseini et al., 2018). Though these triumvirate fields are independent, Hood and Wilson (2001) noted that there has been a confusion in these related terms.

All these techniques entail investigating the dynamics of a research discipline. However, informetrics mainly involve information science that reveals the measurement of circumstances, happenings or occurrence within information (scientific communication). In general, bibliometric analysis and scientometric analysis can be subsumed under informetrics. While bibliometric analysis (library science or library studies) is the

application of mathematical and statistical techniques to articles, books and other communication modes to determine literature output (Ding, 2011), scientometric analysis (science of science) is broader. It involves bibliometric analysis in addition to measuring and analysing the outcome of the literature to determine the practices of researchers and their organizational structures; research and development policies / management; and policy implementation strategies within a research discipline (Hood and Wilson, 2001).

Given the three science mapping tools, scientometric analysis was, therefore, selected based on the aim and objectives of this study. In addition to identifying primary research areas and knowledge structure in the field of study, it was used to identify the actors such as institutions (universities), research communities or individuals that are responsible for driving scientific advancement. Moreover, it was deployed in this review study to aid policy formulation and implementation for sustainable housing. Similarly, due to its multifaceted purposes, scientometric analysis was espoused in studies of Hosseini et al. (2018) and Darko et al. (2020).

2.2 Selection of Science Mapping Tools

Different science mapping tools are used for data analysis. Some of these are classified as specific (or sometimes ad hoc) such as CoPalRed, Science of Science Tool or VOSviewer while Pajek, Gephi or UCINET are grouped under nonspecific science mapping software (Cobo et al., 2012). In the literature, various science mapping software programs are used for data analysis. In review studies conducted by Olawumi and Chan (2018), Song et al. (2016) and Zhao (2017), CiteSpace was used for content analysis as well as for determining the global trend of research. However, a list of software tools used for systematic review can be found in studies conducted by Hosseini et al. (2018) and Börner et al. (2010).

In analysing the features, advantages and drawbacks of the various science mapping tools, Cobo et al. (2011) asserted that there is no tool so powerful and flexible to integrate all key elements of data retrieval, pre-processing, network extraction, normalization, mapping, analysis, visualization and interpretation. Therefore, Cobo et al. (2011) recommended that researchers should deploy more than one software tool for science mapping. Accordingly, the freely available computer programs such as CiteSpace, VOSviewer and Gephi were selected among other science mapping tools for this study. CiteSpace was used for constructing networks that contain few items / nodes and for burst analysis while VOSviewer and Gephi were selected because they provide better graphical representation of large bibliometric maps (Van Eck and Waltman, 2010). Further details

on these tools can be found in [Chen \(2016\)](#); [Van Eck and Waltman \(2010\)](#) and [Gephi, Gephi Tutorial Quick Start \(2017\)](#), respectively.

2.3 Retrieval of Data

Among the primary scientific databases such as PubMed, Scopus, Google Scholar and ISI Web of Science (WoS), Scopus was selected for data collection to achieve the purpose of this study. Arguably, WoS is very robust and contains a comprehensive database of journals that publish on housing studies. Besides, [Chen \(2016\)](#) advocated that the use of WoS prevents data loss and speeds up data conversion in some of the analytical tools of scientometric analysis such as CiteSpace. However, Scopus provides the most coverage of database, and data loss in Scopus could be minimised ([Falagas et al., 2007](#)). Therefore, using the Scopus search engine, thorough search and refinement were carried out for data collection. To ensure a comprehensive retrieval of data, keywords such as ‘affordable housing’, ‘social housing’, ‘public housing’, ‘cooperative housing’, ‘adequate housing’ and ‘sustainable housing’ were adopted from ([Czischke & van Bortel, 2018](#); [UN, n.d.](#)). Additional keywords such as ‘urban housing’, ‘housing affordability’, ‘low income housing’, ‘housing first’ and ‘housing allowances’ were espoused from a review study that was manually conducted by [Stephen & Hoskara \(2019\)](#). Thus, the retrieval of data in the Scopus search engine was conducted using the following code:

```
ALL ("Housing affordability" OR "Affordable housing" OR "Urban housing" OR "Social housing" OR "Cooperative housing" OR "Public housing" OR "Low income housing" OR "Adequate housing" OR "Sustainable housing" OR "Housing first" OR "Housing allowances") AND DOCTYPE (ar) AND PUBYEAR > 1997 AND PUBYEAR < 2018 AND (LIMIT-TO (LANGUAGE, "English"))
```

Some limitation criteria were set to ensure retrieval of adequate and manageable data. The ‘document type’ was limited to only journal articles for the following three reasons. First, journal articles form the most comprehensive and up-to-date collective knowledge base in any given academic field ([Solomon, 2017](#)). Besides, they play a role in ensuring adherence to community standards in conducting research. Furthermore, journal articles are considered the most reputable sources of data because of the rigorous peer review process before publishing such articles. Since this study is a quantitative review of the literature, review articles were excluded to prevent duplications of results. The search results were also refined to include only journal articles published in English language in the past two decades (1998-2017, inclusive). A total of 11,981 bibliographic records were identified and downloaded for the scientometric analysis. A framework for the research methodology is shown in Fig. 1.

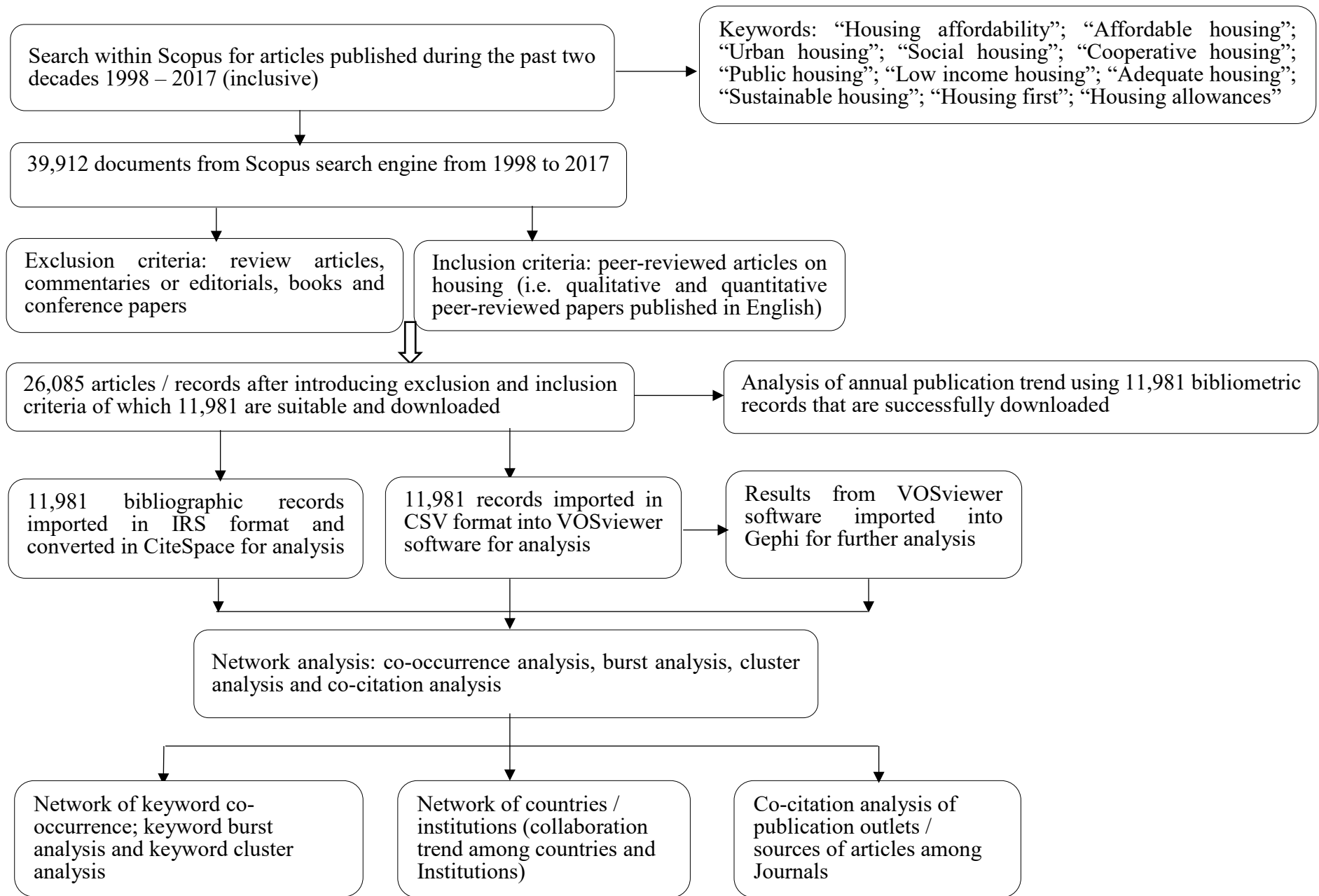


Fig. 1: Framework for Research Methodology

2.4 Metrics in Scientometric Analysis

Scientometric analysis involves many forms of analyses, namely, keyword co-occurrence analysis, keyword citation burst analysis, keyword cluster analysis, country co-citation analysis, institution co-citation analysis and document co-citation analysis etc. (Chen, 2016). In networks, nodes are used to represent keywords, countries and institutions. Connected lines between nodes indicate a certain degree of relationship between nodes. Keyword co-occurrence analysis is the simultaneous occurrence of keywords. It establishes the links or relationships among keywords that mostly occur together in the literature of a research discipline, and it could be used to determine the knowledge structure of that research discipline.

In general, co-citation networks reveal the citing behaviour of nodes in the literature. Therefore, keyword citation burst analysis depicts keywords that have attracted relatively much interest via scholarly publications / citations within certain periods (Ding, 2011). Similar to factor analysis for grouping variables into few interpretable and underlying factors, further analysis of networks (i.e. particularly with keywords) could be conducted for establishing patterns and grouping of nodes for better understanding of the knowledge structure of a research discipline. This form of network analysis is known as cluster analysis (Chen, 2016). Various properties such as degree of a node, betweenness centrality, modularity Q and mean Silhouette score S are used for describing and interpreting outcomes of network analysis.

2.4.1 Degree Centrality of a Node

The degree centrality of a node is a measure of the number of ties / links that a node has with other nodes within a network. It assigns an important score based purely on the number of links held by each node. Degree centrality can be used to find connected nodes, popular nodes and nodes which are likely to hold most information or nodes which can quickly connect with the wider network (Cherven, 2015). To identify the most influential keywords, countries and institutions and their collaboration patterns concerning publications on housing affordability, degree centrality values were calculated for each node using the Gephi software.

2.4.2 Betweenness Centrality

Betweenness centrality shows the nodes which act as “bridges” between nodes in a network. A high betweenness count of a node indicates that the node holds authority over, or controls collaboration between different clusters in a network or that a node is on the periphery of two clusters (Cherven, 2015). Betweenness centrality values for keywords were calculated by first analysing the data in the VOSviewer software to establish a

network of keywords. Then, the network was imported into the Gephi software for calculating the betweenness centrality values. Together with the degree centrality, betweenness centrality values were used for determining the keywords that hold authority in the housing literature.

2.4.3 Modularity Value (Q) and Silhouette Score (S)

In network analysis, modularity value is calculated as the fraction of the links that fall within given groups less the expected fraction if the links were distributed by chance. Thus, modularity reflects the concentration of links inside groups as compared to random distribution of links among nodes. It ranges from -1 to 1 (Chen, 2016). A positive value indicates that the number of links within a group exceeds the number expected based on chance, otherwise the modularity value is negative. For demonstration, if there are χ nodes (i.e. the nodes represent keywords) which are connected by γ number of links and that the nodes can also be divided into cluster A and cluster B with M_v as membership variables, then the modularity is explained as follows: If a node belongs to cluster A, its membership M_v in A is 1. If a node belongs to cluster B, its membership M_v in B is 1. In a network, there may be links connecting nodes in both clusters. Modularity measures the fraction of links that fall within group 1 or 2, minus the expected number of links within groups 1 and 2. Therefore, a high modularity value for a cluster of objects indicates that there is stronger link / collaboration among items in a group /cluster with less links among the items in different group / cluster.

The Silhouette score (S) is a measure of how similar an object is to its cluster (cohesion) in relation to other clusters (separation). Its range is from -1 to 1. A high Silhouette score is appropriate for clustering, and it indicates that an object is well matched to its own cluster or group and poorly matched to neighbouring clusters (Chen, 2016). For example, keywords such as eco-friendly buildings, energy efficient building and green buildings are likely to be grouped under one cluster because such keywords are related to one item – sustainability. In that case, the Silhouette score S for the cluster will be high. However, if the keywords are not related, the Silhouette score S will be low (Song et al., 2018).

3 Analysis, Results and Discussion

3.1 Annual Publications on Housing Affordability

The yearly publication trend of the housing affordability literature was generated from the Scopus search engine using the 11,981 successfully downloaded records (as shown in Fig. 2). Interestingly, within the past two decades (1998 – 2017, inclusive), publications per annum on housing have been increasing steadily as shown by the trend line (straight line) in Fig. 2. The increasing trend of publications infers continual interest and growth in

housing studies. The 11,981 bibliographic records were grouped into various subject areas according to the Scopus subject categories. The top seven research areas generated include: the social science subject category (accounting for 45% of the data set) which has the highest documents; followed by environmental science (accounting for 19% of the data set); engineering (9% of the data set); medicine (6% of the data set); business, management and accounting (5% of the data set); economics, econometrics and finance (4% of the data set) and energy (2% of the data set). However, the subject area with the least number of research articles is material science (accounting for 0.14% of the data set). From the bibliographic records on the Scopus subject categories, the literature / publications on social science and environmental science are relatively high as compared to publications on energy. Similarly, [Yalcinkaya and Singh \(2015\)](#) concluded that the relatively low studies related to energy and its management could be attributed to the fact that energy is still an emerging research theme.

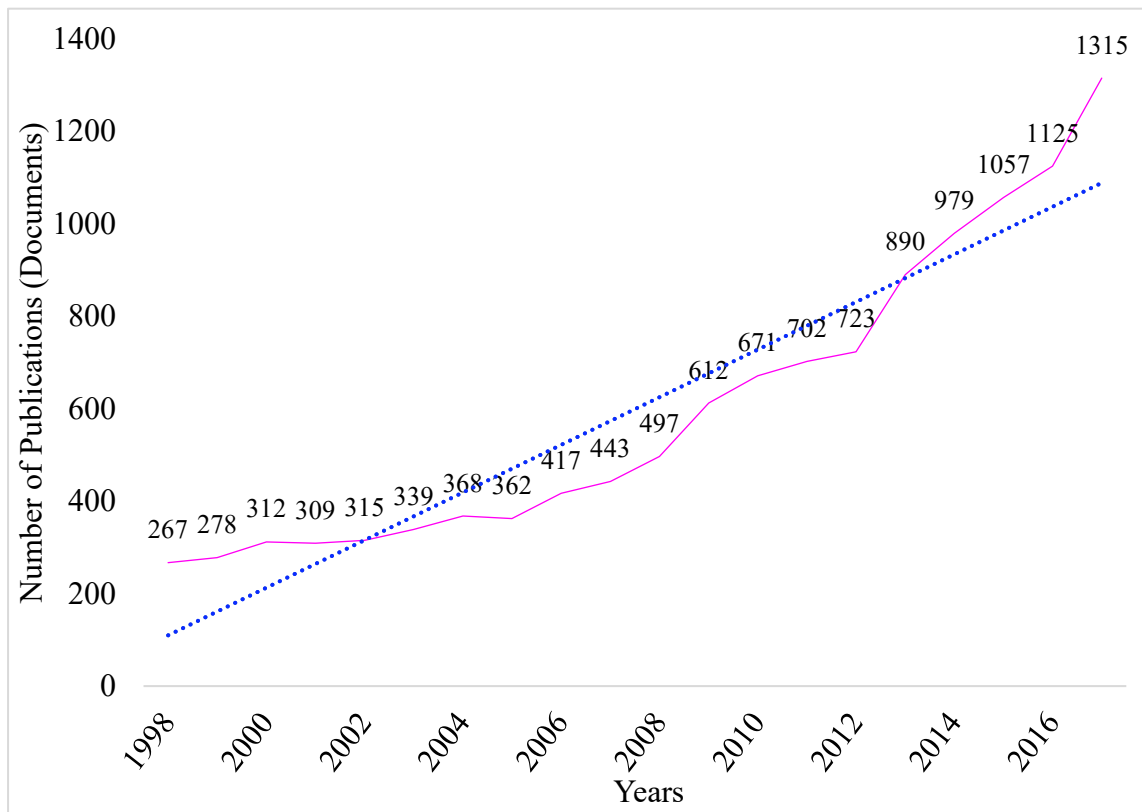


Fig. 2: Annual Publications on Housing Affordability

3.2 Co-Word Analysis

3.2.1 Main research interests: keywords co-occurrence analysis

Keyword analysis aims to determine the main research interests within a research field. A network of keywords reveals the knowledge domain / knowledge structure in the field by showing the existing research interests and how they are intellectually related / connected

to one another and organized. Therefore, VOSviewer 1.6.15 software was deployed for keyword co-occurrence analysis in order to establish the main research interests in the housing literature. Co-occurrence is the simultaneous occurrence of two or more items (i.e. keywords, institutions, countries, journals). In a typical co-occurrence network, the items are represented by nodes while the edges or connecting lines or links represent the relationships among the items. Thus, for keyword co-occurrence networks, the nodes represent the keywords and the edges depict relationships among the keywords. This elucidation also applies in subsequent networks in which keywords are substituted for countries, institutions and journals. Co-occurrence networks are often weighted. As such, in addition to showing the relationships, the links reveal the strength or weight of the relationship among nodes.

In establishing the keywords co-occurrence network, ‘all keywords’ was preferred to ‘author keywords’. The ‘all keywords’ is as effective as the ‘author keywords’ in bibliometric analysis for investigating the knowledge domain of a research field. However, it is more broadly descriptive than the ‘author keywords’. Besides, ‘all keywords’ option was selected instead of ‘author keywords’ to provide a comprehensive view of the keywords used in the housing affordability literature. In this study, fractional counting was chosen over full counting. Fractional counting is a counting method that assigns weights to nodes (i.e. authors, countries, institutions) fractionally in co-authorship networks or co-citation networks. Thus, it provides convenience for reducing the impact of publications with many authors in co-authorship analysis (Darko et al., 2020). However, in full counting, co-authored publications are counted once for each author, which means the overall weight of the publication is equal to the number of authors. This could lead to biases in research fields of multiples authors on co-authored publications.

Using the fractional counting method in keyword co-occurrence analysis, a total of 26,928 keywords were extracted from the bibliometric database. To ensure a manageable number of keywords in the network, the value for minimum number of occurrences of a keyword was set at 110. This inclusion criterion was met by 145 keywords out of the total 26,928 keywords. Identical keywords were merged. For instance, keywords such as ‘housing affordability’ and ‘affordability’; ‘homeless person’ and ‘homelessness’; ‘social segregation’ and ‘segregation’ etc. were merged as ‘housing affordability’; ‘homeless person’; ‘social segregation’ etc. Fig. 3 shows a network of the keyword co-occurrence analysis.

The relevance of the keywords was assessed by importing the network generated from VOSviewer into the Gephi software for estimating other statistics. In the Gephi software, degree centrality (links) and betweenness centrality were estimated for the top 71 keywords that are more specific to the housing literature. The degree centrality of nodes represents one of the most accurate and reliable approaches for determining influential nodes within a network. It indicates the number of links / connection of a node to other nodes (Darko et al., 2020). Essentially, the more degree centrality of a keyword the more influential the keyword. The betweenness count of a keyword is a measure of how the keyword acts as a “bridge” between other keywords in a network. The keywords were ranked based on their degree centrality values. However, for keywords with the same degree centrality, their betweenness centrality values were used to rank them.

Table 1: Influence of Keywords in the Housing Affordability Literature

Label	Degree Centrality (links)	Betweenness centrality	Ranks
poverty	129	36.967	1
neighbourhood	128	35.871	2
urban housing	128	35.612	3
perception	126	33.813	4
urban planning	126	33.444	5
housing conditions	124	32.359	6
comparative study	122	33.762	7
housing policy	122	28.452	8
urban renewal	119	27.034	9
quality of life	118	27.749	10
urbanization	118	24.135	11
employment	117	25.080	12
socioeconomic status	117	24.787	13
risk assessment	116	27.711	14
education	116	24.331	15
income	115	25.488	16
housing market	112	19.970	17
public health	112	19.283	18
residential mobility	111	19.296	19
homeownership	111	19.144	20
gentrification	110	15.672	21
social capital	109	18.148	22
urban policy	109	17.699	23
accessibility	106	18.631	24
crime	106	17.902	25
homelessness	106	15.781	26
sustainable development	105	18.618	27
land use	105	17.038	28
ethnicity	105	16.018	29
greenspace	104	19.278	30
rental sector	104	17.892	31
residential location	104	17.130	32
public policy	99	19.563	33
local participation	99	13.874	34
ethnology	99	12.909	35
tenure system	99	11.958	36

social exclusion	97	12.385	37
housing management	97	11.483	38
middle aged	97	11.408	39
social segregation	97	10.408	40
architectural design	94	13.569	41
informal settlement	94	8.016	42
price dynamics	93	11.726	43
aged	93	10.280	44
social policy	92	11.493	45
public space	92	9.823	46
adolescent	91	9.066	47
land use planning	91	8.080	48
social environment	89	8.552	49
neoliberalism	89	8.526	50
redevelopment	88	8.345	51
social support	88	7.339	52
energy efficiency	87	10.554	53
residential satisfaction	87	8.970	54
community development	87	8.519	55
climate change	85	12.377	56
young adult	84	7.277	57
violence	82	6.309	58
housing finance	80	5.699	59
energy conservation	75	8.859	60
heating	73	8.293	61
welfare provision	71	6.233	62
urban politics	71	3.703	63
land market	69	3.739	64
property market	69	3.050	65
costs	67	6.385	66
energy policy	66	5.514	67
energy use	66	4.700	68
energy utilization	58	3.050	69
mortgage lending	57	1.897	70
ventilation	55	3.724	71

From the results of the keyword co-occurrence analysis (as shown in Fig. 3 and Table 1), some of the keywords that have high degree centrality and betweenness centrality values (as shown in Table 1) are discussed subsequently. ‘Poverty’ has the highest degree centrality and betweenness centrality. Thus, the keyword ‘poverty’ has the highest number of links and influence on most of the keywords, namely, homelessness, informal housing, crime, social exclusion, residential mobility, urban housing, housing conditions, socioeconomic status. Besides, it was linked to certain categories of population (i.e. young adult, aged, middle aged, adolescents). This could imply that most of the housing crises (i.e. price unaffordability and energy poverty) are related to poverty or low-income level of most households. High level of poverty among households is mostly caused by income inequality which influences prices of the limited supplied residential facilities. Therefore, to ensure access to adequate housing by 2030 per the UN sustainable development goal, there is the need for policies that ensure poverty alleviation especially in urban areas. Policies that lead to income growth and decrease in inequality could translate to poverty

reduction. For instance, training and development programs on information technology could be provided to employees and low-income households. This will improve their productivity for better wages which could significantly reduce poverty.

Besides, 'neighbourhood' or neighbourhood development, with betweenness centrality value of 15.781, has much influence on adequate housing. Aside ensuring the provision of housing facilities, neighbourhood development influences the social capital of households. Adequate infrastructure in the neighbourhood for social interactions contributes to building a cohesive community among similar households and households of diverse backgrounds. This could ensure social sustainability attainment for sustainable communities in general, and sustainable housing in particular. For instance, a study by [Adabre and Chan \(2020\)](#) revealed that households' satisfaction through residential and neighbourhood development has the highest impact on sustainable development.

The results of the keyword co-occurrence analysis are also important in identifying key research focuses that are neglected or have low-research outputs. It is worth noting that keywords related to the various forms of housing (such as 'affordable housing', 'public housing', 'social housing' and 'low cost housing') were identified as influential in the housing literature. However, the term 'cooperative housing', though it was included as a keyword in the literature search, was not identified as one of the most influential keywords in the literature. Besides, other keywords that are relevant for sustainable housing but were underrepresented in the network include: 'modular housing', 'prefabricated housing'; 'collective self-build housing'; 'eco-villages'; 'eco-self-build communities' and 'water management'. The underrepresentation of these relevant keywords / research focuses in the network could be attributed to their low uptake and limited studies in relation to housing. Yet, to ensure adequate housing accessibility and urban redevelopment of slum areas, for example, there is the need for co-operative housing in slum communities. Further, considering the problem of water scarcity and the over-exploitation of ground water in some sub-Saharan African countries, studies and policies are required to ensure groundwater sustainability. Additionally, although circular economy is encouraged in housing to reduce wastage in recycling of materials, it did not co-occur with any of the keywords that were employed in the literature search. This could also be alluded to the fact that circular economy in housing development is still an inchoate research focus.

Moreover, it is worth noting that artificial intelligence (AI), a promising concept for sustainable communities and sustainable housing, did not co-occur with any of the keywords used for the literature search. Yet, its wide technologies such as robotics, machine learning (ML), image recognition, Artificial Neural Network (ANN) model,

genetic algorithm, support vector machine and fuzzy set theory could be applied to solve housing-related problems. These technologies could serve as tools to pre-empt contributory factors of the unaffordable crisis such as poverty, slums, energy crises, pollution and traffic congestion for sustainable cities and sustainable housing. For instance, the application of ANN model and genetic algorithm could enable the UN and local governments to accurately estimate housing demand and improve occupants' thermal comfort (Ren et al., 2015). This could solve the problem of housing overhang as a result of housing demand-supply mismatch (Maimun et al., 2018). Ambient assisted living could be deployed to provide safe, quality and independent lives for the very elderly in society. Robotic vacuum cleaner and vision-based systems are necessary for collecting dirt and for surveillance and monitoring (crime control), respectively. The application of fuzzy set theory in efficient risk allocation could incentivize effective participation of the private sector in housing supply (Osei-Kyei & Chan, 2017). Therefore, considering the limited literature yet importance of AI in housing, R & D policies on the application of AI to mitigate the unaffordability crisis are essential at local and national level.

Notwithstanding its relevance, keywords co-occurrence analysis together with degree centrality values and betweenness centrality values only provides a static structure of the body of knowledge in the housing literature. It does not show the level of interest on the keywords by researchers over changes in time. Thus, the outcome of the keyword co-occurrence analysis provides the “paradigm” or structure of knowledge in the literature, but it does offer the “paradigm shift” or changes in interest on the various structures of knowledge in a field of study.

3.4.2 Keyword Citation Burst

Based on the limitation of the keywords co-occurrence analysis, keyword citation burst was conducted. Citation burst represents notable increase in citations of keywords which can occur over multiple years or a single year. Thus, it shows the keywords that are frequently cited in the literature within a given period. According to He et al. (2017), keyword citation burst can be used to indicate transient and emerging research focuses / trends in the housing literature within a specific period. It was conducted to reveal development or changes in interest on the knowledge structure of the housing literature over the past two decades. Such analysis is also essential for establishing overlooked knowledge / research gaps within certain periods and the need for further studies on the identified knowledge gaps. Citation burst analysis is based on Kleinberg's algorithm (Chen, 2016). Pollack and Adler (2015) stated that the burst detection algorithm shows an unusual large change in frequency of a datum over time.






Therefore, keywords citation burst was conducted using the CiteSpace tool. Table 2 shows the keywords that gained / attracted interest in the housing literature published in the past two decades (from 1998 to 2017). The citation burst for a keyword is represented by the red bar/ line while the literature review period of two decades is represented by the light green bar or line. Among the keywords with burst strength above 15 include: 'housing policy' (citation burst strength of 107.795, from 1998 to 2004); 'energy efficiency' (citation burst strength of 25.213, from 2015 to 2017); 'energy utilization' (citation burst strength of 23.787, from 2015 to 2017); 'rental sector' (citation burst strength of 20.668, from 1999 to 2005); 'social segregation' (citation burst strength of 19.787, 1998 to 2005); 'housing association' (citation burst strength of 19.306,, from 1999 to 2010); 'welfare provision' (citation burst strength of 18.303, from 2000 to 2005); 'social housing' (citation burst strength of 17.542, from 1999 to 2004); 'apartment house' (citation burst strength of 16.289, from 2009 to 2012); and 'self-help' (citation burst strength of 15.326, from 1998 to 2003). Besides, trending research topics based on their recent citation bursts (i.e. citations spanning to 2017) include: inequality, public service, retrofitting, health (i.e. health care delivery and health policy), some populations (i.e. very elderly, young adults, vulnerable population), transportation, environmental protection, emission control, energy (i.e. energy efficiency and energy utilization), environmental justice and displacement.

From the results of the keyword citation burst analysis, it can be concluded that there is high interest in the literature on significant research focuses. High research interest on research topics (i.e. energy efficiency, retrofitting, green buildings, emission control, residential satisfaction and social mix) is important for sustainable development in housing. Such outburst in research interest on these research topics, evinced in their citation burst, could inform both local and national decision making for sustainable housing. However, the results of the burst analysis also revealed keywords that have received less research attention based on their relatively low burst strengths (i.e. < 5). Some of these keywords include: demolition, neoliberalism, gated communities, urban design, mortgage, health care delivery, public service, social exclusion, housing location or location decision; neighbourhood effect; life cycle analysis of housing facilities; energy management, ventilation, participatory research, architectural design / passive housing and household energy. These keywords require more research attention considering their impact on sustainable housing.

Table 2: Top 94 Keywords with their Citation Burst Strengths

Keywords	Year	Strength	Begin	End	1998 - 2017
housing policy	1998	107.795	1998	2004	
service provision	1998	4.206	1998	2001	
violence	1998	9.222	1998	2004	
immigrant population	1998	10.991	1998	2004	
ethnic minority	1998	13.451	1998	2003	
social segregation	1998	19.787	1998	2005	
self help	1998	15.326	1998	2003	
homeownership	1998	5.595	1998	2000	
development control	1998	7.115	1998	2002	
urban renewal	1998	8.269	1999	2006	
social housing	1998	17.542	1999	2004	
housing association	1998	19.306	1999	2010	
transitional economy	1998	4.663	1999	2004	
urban planning	1998	5.120	1999	2003	
rental sector	1998	20.668	1999	2004	
financial provision	1998	16.577	1999	2005	
welfare provision	1998	18.303	2000	2005	
housing market	1998	12.723	2000	2003	
non-profit organization	1998	3.447	2000	2007	
land tenure	1998	11.908	2000	2010	
racial segregation	1998	13.232	2000	2010	
economic regeneration	1998	10.199	2001	2006	
crime	1998	3.334	2001	2002	
mortgage	1998	4.633	2001	2005	
economic and social effect	1998	7.012	2001	2006	
urban design	1998	3.676	2001	2003	
housing career	1998	5.894	2002	2003	
social aspect	1998	13.897	2002	2008	
international comparison	1998	4.584	2002	2003	
housing assistance program	1998	7.342	2003	2005	
substance abuse	1998	5.974	2004	2011	
nongovernmental organization	1998	4.342	2004	2011	
environmental impact	1998	4.029	2005	2006	
architectural design	1998	3.448	2005	2007	
community based participatory research	1998	3.155	2006	2011	
ambient air	1998	4.146	2006	2009	
housing management	1998	5.053	2006	2007	
settlement pattern	1998	8.356	2007	2010	
housing finance	1998	6.132	2007	2008	
community care	1998	6.391	2007	2012	
residential satisfaction	1998	6.152	2008	2010	
social exclusion	1998	3.961	2008	2009	

apartment house	1998	16.289	2008	2012	
neighbourhood	1998	4.627	2009	2014	
ventilation	1998	3.160	2009	2010	
fear	1998	6.737	2009	2012	
subsidy system	1998	6.526	2009	2011	
urban regeneration	1998	6.434	2009	2012	
demolition	1998	3.456	2009	2013	
location decision	1998	4.705	2010	2013	
suburbanization	1998	8.690	2010	2013	
ethnology	1998	12.362	2010	2012	
housing reform	1998	4.157	2010	2011	
hope vi	1998	6.833	2010	2011	
neoliberalism	1998	3.738	2010	2013	
public private partnership	1998	5.275	2011	2012	
young adult	1998	7.411	2011	2017	
social justice	1998	6.079	2011	2017	
neighbourhood effect	1998	4.508	2012	2015	
life cycle analysis	1998	4.227	2012	2013	
social interaction	1998	12.822	2012	2017	
building code	1998	6.387	2012	2015	
gated community	1998	3.773	2012	2014	
multi-storey building	1998	7.171	2012	2013	
environmental management	1998	7.242	2013	2017	
foreclosure	1998	7.571	2013	2017	
carbon emission	1998	5.460	2013	2017	
land management	1998	5.523	2013	2014	
social isolation	1998	9.927	2013	2015	
social mix	1998	9.234	2013	2015	
household energy	1998	3.954	2013	2017	
relocation	1998	6.299	2013	2017	
price determination	1998	8.800	2013	2017	
environment design	1998	5.281	2013	2017	
financial crisis	1998	5.829	2013	2017	
green building	1998	6.131	2013	2015	
inequality	1998	10.015	2014	2017	
risk taking	1998	3.262	2014	2017	
public service	1998	3.718	2014	2017	
land use change	1998	4.958	2014	2015	
retrofitting	1998	13.433	2014	2017	
health care delivery	1998	3.904	2014	2017	
very elderly	1998	13.662	2015	2017	
transportation	1998	10.654	2015	2017	
housing first	1998	7.376	2015	2017	
environmental protection	1998	6.041	2015	2017	
emission control	1998	9.825	2015	2017	
energy efficiency	1998	25.213	2015	2017	

environmental justice	1998	8.302	2015	2017	
displacement	1998	6.627	2015	2017	
energy utilization	1998	23.787	2015	2017	
health policy	1998	6.143	2015	2017	
vulnerable population	1998	12.554	2015	2017	

Legend



Denotes the duration of a citation burst for a keyword



Denotes year range for the entire literature review

3.4.3 Comparing Results of Keyword Co-occurrence and Keyword Citation Burst

A critical look at the keyword co-occurrence analysis in comparison with the keyword citation burst analysis provides fascinating findings. Some of the keywords that have high degree centrality and betweenness centrality did not have citation bursts. For instance, keywords such as ‘poverty’, ‘quality of life’, ‘employment’, ‘greenspace’, ‘local participation’, ‘informal settlement’, ‘land use planning’ and ‘climate change’ have relatively high weights and high betweenness centrality values (as shown in Table 1). However, they were not among the list of keywords with citation burst. This suggests that there have been steady increasing publications and citations on these keywords. It also indicates that these keywords are some of the consistent terms in the housing literature. As such, there are no sudden citation hikes or bursts. It is worth noting that burst detection shows rapid changes in frequency and not total frequency. Therefore, a keyword may burst in popularity and yet remain less significant on consistently high frequency in terms of publications and citations.

The keyword co-occurrence analysis and keywords burst detection analysis provide insight into the knowledge structure (paradigm) and trends in the knowledge structure (paradigm shift) of the literature. However, they do not illustrate the main groups / clusters of the knowledge structure in the housing affordability literature. Determining the categories of the knowledge structure requires cluster analysis of the keywords.

3.4.4 Categorization of Keywords into Clusters

Through cluster analysis, the numerous keywords concerning the housing literature could be classified into manageable clusters. Cluster analysis can be considered as a data reduction technique that facilitates the categorization of large body of keywords into related manageable units. It employs a set of algorithms in grouping unstructured texts / keywords into structured units of data for knowledge discovery (He et al., 2017). Each unit contains a group of related keywords with high intra-class similarity. Such clusters could further provide insight into the knowledge structure of the housing literature.

Cluster analysis was carried out using CiteSpace to group the keywords into themes. The Log-Likelihood Ratio (LLR) (for more information please see [Chen, 2016](#)) was selected because of its best-quality cluster formation in terms of uniqueness and coverage. Fig. 4 shows the four largest clusters that were generated in the CiteSpace tool, while Table 3 contains the cluster ID, size, silhouette score S, cluster label (LLR) and mean year. The mean year shows if the cluster was formed by recent or old documents ([Olawumi and Chan, 2018](#)). The average homogeneity (tightness and separation) of a cluster is given by the Silhouette score while the modularity of the clusters measures the connectivity. A high modularity value indicates high connectivity among clusters. However, a relatively low overall modularity value (0.416) was estimated for the clusters which shows that there is a moderate connectivity among the clusters. This is further buttressed by a generally low estimated Silhouette score S (0.133). Therefore, the overall modularity and Silhouette values show that these clusters are moderately related. Thus, they have moderate separation ([Hanlon, 2010](#)).

The clusters are ranked based on the number of keywords in each cluster (size). Though the overall Silhouette score is low, the Silhouette value for each cluster (shown in Table 3) is high. The high Silhouette score for each cluster shows that there is high homogeneity of the members in each cluster. Thus, the higher the Silhouette Score S, the more consistent the cluster members / keywords. Subsequent sections explain the various clusters that were generated.

Table 3: The Top Four Keyword Clusters

Cluster ID	Size	Silhouette Score	Cluster Label (LLR)	Mean Year
0	318	0.786	Self-help housing	2004
1	212	0.880	Homeless adult / Homelessness	2005
2	137	0.841	Thermal comfort	2008
3	101	0.794	Residential segregations	2004

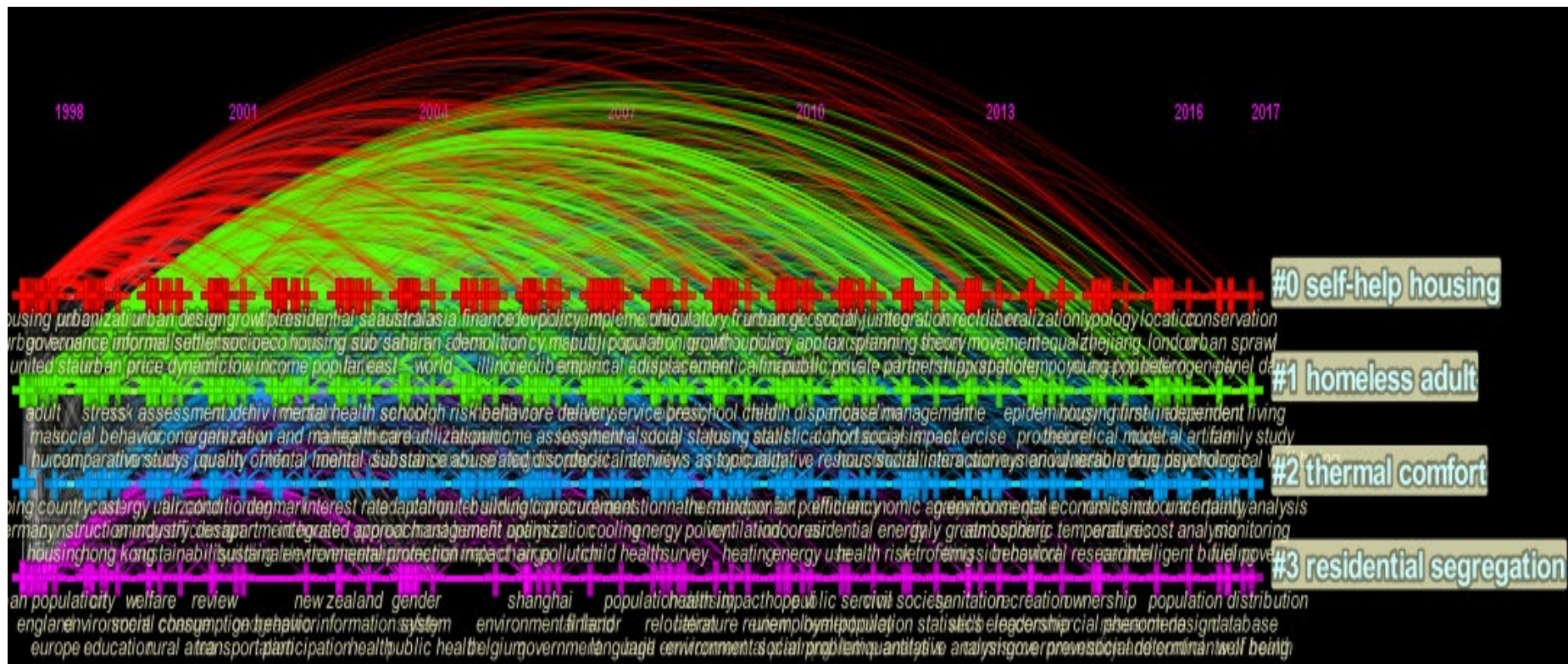


Fig. 4: Keywords Cluster Analysis

Cluster # 0, labelled ‘Self-help housing’ is the largest cluster with a size of 318, a Silhouette score of 0.786 and mean year of 2004 (shown in Table 3 and Fig. 4). Some of the most frequent keywords under this cluster include: neoliberalism; public private partnership; devolution; slum; peripheral development; capitalism; deprivation; social justice; financial system; financial crisis; suburbanization; low-cost housing; competition (economics); displacement; socioeconomic impact; settlement pattern; rent control; redevelopment; economic growth; land management; housing affordability; social capital; housing allowance; home ownership; accessibility; housing association.

The largest size of this cluster is an indication of the global increasing demand for housing supply through self-help. This could be attributed to the ‘neo-liberalisation of welfare’ among countries. In most countries, there has been a devolution of governments’ role in housing supply to the citizens. Though some public facilities are provided, most citizens are responsible for their welfare including housing supply. Through self-help housing, most households solve their shelter needs primarily through their own resources of labour and finance (Bangdome-Dery et al., 2014). Self-help housing could be aided self-help, unaided self-help housing (self-build housing) or institutional self-help housing (cooperative housing). Among these forms, unaided self-help / laissez-faire / self-build housing is common in most countries.

Self-build housing is any form of housing where the first occupants of a new home are involved in its production, either by arranging for its construction (custom build i.e. self-build involving a developer) or being involved in building it themselves to some degree (Hefferman & De Wilde, 2020, p. 2). Following neoliberalism in housing supply among developing economies in most sub-Saharan African countries, there has been massive development of policies to augment self-build housing. Similarly, self-build housing has been a key supply of housing in most developed economies (McKee, 2012). For instance, at least 50% of the homes are self-built in the case of Austria, Belgium, Italy, Sweden, Norway, Germany, France, Ireland, Switzerland, Finland and Canada (Broer & Titheridge, 2010). This form of self-build housing is individual, and it ensures social sustainability through residential satisfaction. However, significant sustainable development could be achieved through institutional self-help housing which is also referred to as collective self-help housing or group self-build housing.

Ensuring group self-build housing world-wide could fast-track the achievement of the UN Sustainable Development Goal of adequate housing. Comparatively, group self-build housing has higher potential of ensuring energy efficiency, affordability, quality housing, innovative design and construction, residential satisfaction and sustainable communities than those supplied by speculative developers (Hefferman & De Wilde, 2020). A typical

group self-build housing project – the Amui Dzor Housing Cooperative in a sub-Saharan region – was established as a means of upgrading a slum community (Gillespie, 2018). The housing facilities developed by this cooperative are relatively affordable because of the pooling together of resources (i.e. land and labour from the participants / stakeholders), economies of scales attributed to division of labour and adoptions of more efficient techniques in housing construction. Besides, the group’s interest in the housing facilities as a long-term investment and their interest in reducing the running cost promote a team spirit for ensuring energy efficient housing. Moreover, by working together as a group, group self-builders could develop bonds among themselves and other households of their neighbourhood. These forms of bonds are essential for social sustainability in addition to serving as checks on the members of the group to avoid energy wastage as a result of the lifestyle choices of members. The latter is achieved through information sharing or awareness-raising among members. Finally, between developers and group self-builders, the latter are less risk averse. Thus, they are more receptive of new sustainable technologies or methods, which could facilitate transition of sustainable housing techniques from niche to mainstream housing (Hefferman & De Wilde, 2020).

Despite its importance, group self-build housing has received less attention in the housing literature. This is evinced in the keyword co-occurrence network (Fig. 3) since group self-build did not meet the minimum selection criteria to be represented in the network. Moreover, attaining its benefits has been hindered by challenges. Notable among them include difficulties in obtaining finance, challenges in obtaining land and commitment-related challenges (i.e. time consuming) (Hefferman & De Wilde, 2020). To mitigate some of these challenges, financial policies such as interest-free loans and revolving fund could be established as strategies by the UN and local governments to assist group self-build housing. Besides, governments can promote it by arranging the release of plots to prospective group self-builders (Dol et al., 2012). Furthermore, expedited permitting and levy-exemption policies could alleviate some of the bureaucratic barriers and therefore, advance the activities of this housing. Moreover, policies on training and education concerning exemplary leadership and partnering between group self-builders and developers are essential. These policies are relevant for facilitating access to low-interest loans from banks and for ensuring knowledge transfer on sustainable housing techniques from developers to group self-builders.

Cluster # 1, labelled ‘Homeless adult’ is the second largest cluster. It has a size of 212 with Silhouette score of 0.880 and mean year of 2005 (as shown in Table 3 and Fig. 4). Homelessness entails living in a housing facility that lacks adequate tenure security or that is below the minimum required standard for adequate housing or living. A homeless person could be living in the streets; moving among temporary shelters (such as facilities

of friends, families or emergency housing). Some of the keywords under this cluster include: drug dependence; supported housing; vulnerable population; poverty area; health disparity; young adult; student; child abuse; minority group; substance related disorder; Hispanic American; drug use; disease association; mental disease; addiction; hiv infection; smoking; educational status; homeless person; income; adult; aged; middle aged; African American. While some of these keywords include the populations that are vulnerable to homelessness, most of the other keywords are contributory factors.

Globally, studies have shown that those mostly excluded from accessing adequate housing are young adults (McKee, 2012; Xu et al., 2015; Filandri & Bertolini, 2016). Following the Global Financial Crisis, many young adults and middle-aged persons find it difficult to access adequate housing, especially for ownership. Stringent credit conditions, high unemployment rate and student loan have been identified as the causes of the inadequate accessibility crisis among young adults (Xu et al., 2015). In response to the financial crisis (Great Recession), lenders have tightened mortgage standards. Relatively high down payments are required, which makes it difficult for young adults to access mortgage facilities for homeownership. Besides, compounding interest on student loans have affected students' ability to make savings for homeownership in the short-term of taking up a job offer. Furthermore, outstanding student loans could negatively affect young adults' credit score. Credit score influences both the accessibility and interest rates on mortgages. Consequently, an aversion of additional debt and lack of mortgage facilities due to low credit score could greatly affect homeownership. Moreover, possible reverse transfer of financial support from young adults to support their parents could delay young adults' access to homeownership. Thus, homeownership is mostly a long-term goal due to some of these challenges.

Notwithstanding the difficulties that this cohort faces in accessing home ownership, young adults' preference for homeownership over renting in the long term has not changed. Most are still expectant of becoming homeowners 'at some time in the future'. Yet, greater flexibility and geographic mobility / residential mobility for occupational reasons are some of the factors that motivate rental facilities in the short term among young adults. Thus, in order to be mobile, most young professionals would prefer to rent even though they could afford homeownership (Filandri & Bertolini, 2016). However, high advance lump-sum rental payments, lack of tenure security and inadequate rental facilities have often contributed to the homeless situations of this cohort. Some young adults reside with friends or family members in order to make enough saving for the high advance payments of rental facilities (McKee, 2012).

Considering the general unaffordability crisis and the fact that most young adults are itinerant, ensuring rental affordability globally could promote sustainable development in housing. For instance, prefabricated housing facilities made of keetwonen (containers) could serve as makeshift facilities for most young adults in major cities. Aside providing space flexibility, this form of housing saves time and money on housing construction. Besides, such temporary facilities could be transported to other areas for reuse or when needed while possible redevelopment of the previous site could take place or for the land to revert to the owner (Kim & Kim, 2016). This form of modular housing requires policy support from government on the use of idle plots of land in highly urbanized areas to ease inadequate housing crisis. In countries where land is owned by the individuals, families or chiefs, there is the need for policies that encourage partnership between land owners and potential developers of container housing. Through a contractual arrangement, a developer could pay land rent for a stipulated period. This could enable the developers to provide housing facilities for young adults for an agreed period.

Cluster # 2, labelled ‘thermal comfort’ is the third largest cluster of size 137. Its Silhouette score is 0.841, and its mean year is 2008 (as shown in Table 3). Increasing emission of greenhouse gases has caused changes in climatic conditions. This has led to exacerbated extreme indoor temperature effects of cold or warm discomfort. Extreme indoor temperatures could lead to heat-related health problems and mortalities (Sakka et al., 2012). For instance, the intensity of shivering, a physiological response to cold, could affect resistance to respiratory disease and possible cardiovascular stress among the aged (Healy & Clinch, 2002). Households could respond to this situation through behavioural and technological adjustments. Behavioural adjustment entails altering one’s behaviour while technological adjustment mostly involves efficient utilization of building energy for achieving thermal comfort (Soebarto & Bennetts, 2014). Therefore, thermal comfort is influenced by physiological, psychological, environmental and technological variables. As such, some of the keywords which were classified under this cluster relate to one or more of these variables, namely, occupant behaviour, adaptation, aging, climate change, environmental condition, ambient air, cooling, air pollution, ambient temperature, residential energy, greenhouse gas, carbon dioxide, atmospheric temperature, home environment, thermal performance, air quality, energy use, energy efficiency, architectural design, retrofitting, building code, solar energy, space heating, green building; indoor air quality and environmental sustainability.

Considering the constant changing climatic conditions as a result of increasing emission of greenhouse gases, thermal comfort remains a topical issue for sustainable housing worldwide. Significant development or progress has been achieved on some of the technologies or technological adjustments for thermal comfort. However, a study by

[Adabre et al. \(2020\)](#) revealed that their adoption in residential facilities has been hindered globally by inadequate incentives. Therefore, to ensure the attainment of the UN sustainable development goals in housing, there is the need for policies that could encourage households to retrofit their home to energy efficient standards. For example, subventions that are directed to low-income households could incentivize energy efficient retrofitting. Subsidies on passive strategies could enable low-income households to afford internal blinds for windows and reflective coatings on roofs for regulating solar radiations into buildings. Besides, improved awareness programmes / information dissemination on health-related problems as a result of cold and warm discomfort could serve as a negative reinforcement strategy for motivating energy efficient retrofitting in housing. Furthermore, policies that encourage high thermal mass or heavyweight housing in tropical countries are essential for thermal comfort ([Adekunle & Nikolopoulou, 2016](#)). Moreover, R & D policies on the application of some technologies of artificial intelligence (i.e. artificial neural network (ANN) and support vector machine (SVM)) on modelling households' energy consumption pattern could enhance space heating or cooling and thermostat use in housing facilities ([Ren et al., 2015](#)). Such applications could reduce energy inefficiencies attributed to occupants' behaviour in buildings.

Cluster # 3, labelled 'Residential segregation' has a size of 101. Its Silhouette score is 0.794, and its mean year is 2004 (as shown in Table 3). It is ranked forth based on its cluster size. Some of the keywords classified under this cluster include: racial segregation; social exclusion; neighbourhood effect; social isolation; gated community; crime; inequality; globalization; gentrification; urbanism; governmentality; forced relocation; social problems; unemployment; hope vi; environmental planning; relocation; population density; antisocial behaviour; transportation; rural area; social change; education; density; residence characteristics and policy. It is worth noting that some of these keywords are contributory factors of residential segregation.

Residential separation has been a major problem between high income earners on one hand and middle- and low-income earners on the other hand. Besides, peri-urban development of government or public housing facilities contributes to segregation. Additionally, gentrification and globalization have often exacerbated residential segregation. Moreover, it could occur within cities in which some communities are segregated from other households. A typical case is gated community development. Increasing desires for safety and privacy among households have led to increasing development of gated communities and fenced private / self-build housing facilities. This trend of development is as a result of increasing poverty and income inequality which intensify crime rates and the fear of crimes among households. Yet, it is to be noted that though gated facilities may provide safety, they may not ensure a holistic sustainable

community. Community development could be destroyed since gated communities may not ensure community cohesion and social capital.

Residential segregation could negatively affect sustainable development. It leads to rise in slum development, faster depletion of peri-urban land and increase commuting cost and vehicular emission alluded to increased distance between cities and households in peri-urban housing facilities. Therefore, various strategies have been adopted in countries for enhancing social diversity and mixed communities (Solé, 2006). For example, in England, the Planning Policy Statement 3: Housing, highlights the need to create mixed and inclusive communities. French land-use law (Art. 1 of the loi orientation pour la ville) confirms social cohesion through mixture of urban function and social mix (Ponce, 2010). In the case of USA, inclusionary zoning is adopted as a fight against segregation by promoting mixed development in housing (Brunick, 2004). For effective mixed development, the income gap among households should be moderate.

3.4.5 Network of Countries / Regions

A network was generated to determine the contribution and collaboration pattern among countries in the housing literature. This is important for research and development policies on promoting comparative studies and collaborative research activities among countries for knowledge sharing or policy transfer and for effective global policy formation (Chen, 2016 and Darko et al., 2020). Therefore, a network diagram of countries was first created using the VOSviewer software. “Co-authorship” was chosen as the analysis technique with “countries” selected as the unit of analysis. The “fractional counting” method was also selected. Moreover, the “minimum number of documents of a country” and the “minimum number of citations of a country” were both set to 10 for achieving an optimum network. Of 181 countries identified, 60 countries met the threshold and were included in the network.

For more clarity on the contribution and the strength of collaboration among countries, the network was imported into the Gephi tool. The countries were ranked and resized using the weighted degree values in Gephi. Higher weighted degree values are reflected in the size of the node (as shown in Fig. 5). Weighted degree, a modified form of degree centrality, is a measure of the number of connections of a node (i.e. country) to other nodes (i.e. countries) in a network. Thus, the bigger the size of a node of a country, the higher the number of connections of the country to other countries in the network. The level of link among countries (shown by the thickness of the connecting lines) is determined by the link strength. The link strength depicts the collaboration strength among countries with regard to the housing affordability literature. A bigger connecting line (link) between two countries indicates a stronger collaboration in terms of article publications. Fig. 5 is a

network analysis of which countries are the actors. It illustrates international collaboration among the countries with regard to the housing affordability literature. Table 4 shows the top 29 contributors to the housing literature. It shows the countries, number of publications (documents), the weighted degree values and ranks of the countries. The ranks are based on the weighted degree values. However, for countries that have the same weighted degrees, the number of publications is used to rank them.

Fig. 5 and Table 4 reveal interesting findings on research collaboration and contribution of some countries. The United States, United Kingdom, China, Australia, Netherlands, Canada, Germany, South Korea, France, Singapore, Sweden and Spain, in descending order of weighted degree values (number of links / collaborations), are the top 12 countries. Besides, these countries have relatively high number of publications (documents) on housing. Therefore, these countries are the most collaborators and contributors in the housing literature. The highest links / connection (an indication of collaboration strength) between countries were observed among the following pairs: United States-China; United States-United Kingdom; United States-Canada; United States-Australia; United Kingdom-Netherlands; China-Australia; United Kingdom-Australia; United Kingdom-Canada. Except for China that is a developing country in these pairs, the other countries are developed countries / economies. One possible reason for the strong link strength among these countries could be cross-country case studies and comparative studies. This is not surprising considering that ‘comparative studies’ and ‘international comparison’ were highlighted in the keyword co-occurrence analysis and keyword citation burst analysis. However, comparative studies and studies on international comparison are mostly conducted among developed countries / economies. Similarly, [Yetgin and Lepkova \(2007\)](#) stated that although there are few comparative studies, most of them are conducted among developed countries.

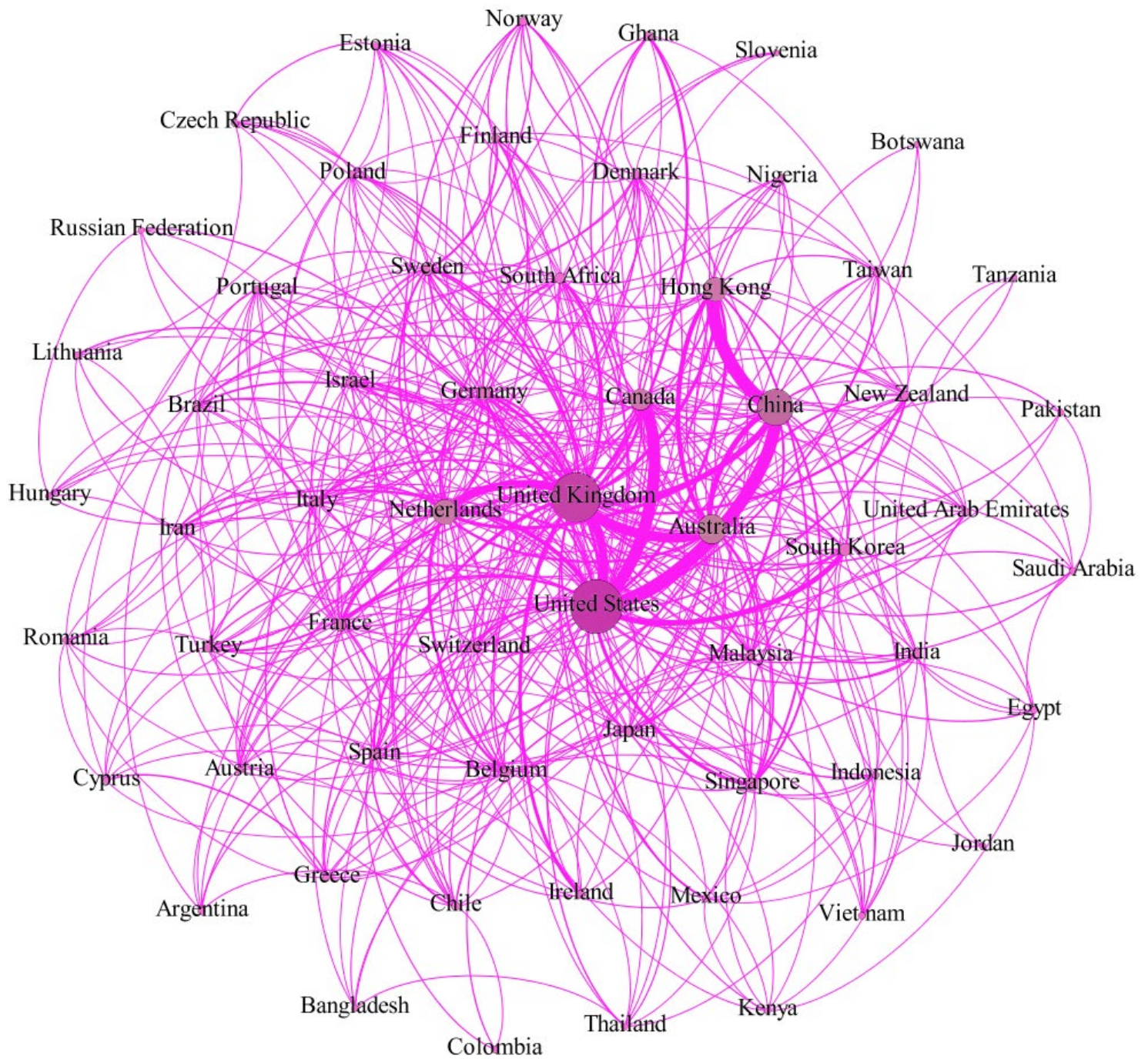


Fig. 5: Network of Collaboration among Countries in the Housing Affordability Literature

Table 4: Top 29 countries collaborating in housing research

Countries	Number of Publication	Weighted Degree Value	Relative Influence
United States	4051	572	1
United Kingdom	2147	527	2
China	549	363	3
Australia	1065	276	4
Netherlands	691	232	5
Canada	722	183	6
Germany	223	93	7

South Korea	182	76	8
France	156	72	9
Sweden	223	71	10
Singapore	211	71	11
Spain	190	62	12
Italy	186	54	13
South Africa	224	53	14
Japan	115	47	15
New Zealand	127	46	16
Malaysia	137	45	17
Switzerland	72	39	18
Belgium	98	38	19
Turkey	131	33	20
Denmark	88	32	21
Ghana	48	31	22
Brazil	98	30	23
Ireland	95	30	24
Norway	87	27	25
Chile	54	26	26
Finland	70	25	27
India	72	24	28
Israel	101	23	29

From the collaboration strength (as shown in Fig. 5) and the documents and weighted degree per countries (as shown in Table 4), most countries such as Malaysia, Switzerland, Belgium, Turkey, Denmark, Ghana, Brazil, Ireland, Norway, Chile, Finland, India and Israel have relatively low weighted degree values and low number of publications (documents). Thus, these countries have low level of collaboration with other countries in comparison with the collaboration level of the United States, United Kingdom, China, Australia, Netherlands and Canada. This finding is important for policymakers in these countries to improve their research policies for possible technology transfer, since they have relatively low collaboration in the housing literature.

The weak collaboration and the less representation of most developing countries (as shown in Fig. 5 and Table 4) could lead to policy biases when international policymakers rely on the housing literature to make global policies on housing. Thus, global policies could be influenced by the dominant studies from the most influential countries. In such situation, initiated policies on adequate housing might not be applicable to the under-represented countries because of different cultures of households and different socio-economic challenges of each country. This could lead to policy inefficiencies. A typical case of this is the adoption of neoliberalism policies among some developing countries in sub-Saharan Africa. This was advocated by international organization such as the World Bank. However, study by [Keivani & Werna \(2001\)](#) revealed that though such policies are relevant among most developed countries and are relatively successful in housing supply, these policies have led to increasing income inequality and increasing slums among some sub-Saharan African countries. This case shows the challenge that could occur if global

policies are established based on the housing literature. Therefore, for effective global policies on housing using the housing literature as a guide, research and development (R & D) programs that encourage international collaboration should be established. These R&D program could improve scholarly communication among countries especially from the underrepresented countries, which could enrich the literature for effective global policies.

Policies or scholarship programs that motivate comparative studies are essential for strengthening the collaboration links among countries for possible policy / knowledge transfer. It cannot be gainsaid that there is no one unified model of sustainable housing and that each country and culture has its own sustainable housing model. However, the same technologies (i.e. ANN and SVM) and approaches could be implemented or adapted by a country from another country through comparative studies to solve similar problems. Furthermore, comparative studies provide information on the concerned countries about their social and economic situation and government policies, that can enhance housing policies development through knowledge sharing (Yetgin and Lepkova, 2007). Differences and similarities observed in comparative studies have aided decisions making in notable comparative studies conducted by Gurran and Whitehead (2011) between Australia and UK; Taltavull de La Paz and Gabrielli (2015) between Spain and Italy and Jiménez and Koebel (2007) between Spain and America. A typical case study was conducted by Agyemang & Morrison (2018) concerning policy transfer on land use planning from the United Kingdom for housing supply in Ghana and other sub-Saharan African countries. The differences and similarities observed in such studies could aid decision making both locally and internationally. Therefore, comparative studies among developed and developing countries are essential for knowledge / policies transfer for improving housing supply strategies globally.

3.4.6 Network of Institutions

Studies have shown that collaboration through networking of institutions contributes to scientific productivity among institutions and development of international research policies (Abramo et. al., 2009). Moreover, according to Ding (2011), identifying the institutions with high interest and collaboration is of benefit to any discipline, especially for contacting or forming partnership among the institutions to provide input for decision making or policy formation. Therefore, a network of institutions was created to find out the collaboration pattern of institutions concerning the housing literature. Institutional network was generated using VOSviewer tool. “Co-authorship” and “organization” were selected as the analysis technique and the unit of analysis, respectively. The “fractional counting” method was also selected. The “minimum number of citation of an organization” and “minimum number of documents of an organization” were both set at

nine (9) for generating the institutional network. Among 18,688 organizations identified, 32 institutions met the threshold. The network was further visualized using Gephi (as shown in Fig. 6). The total number of links in the network is 22.

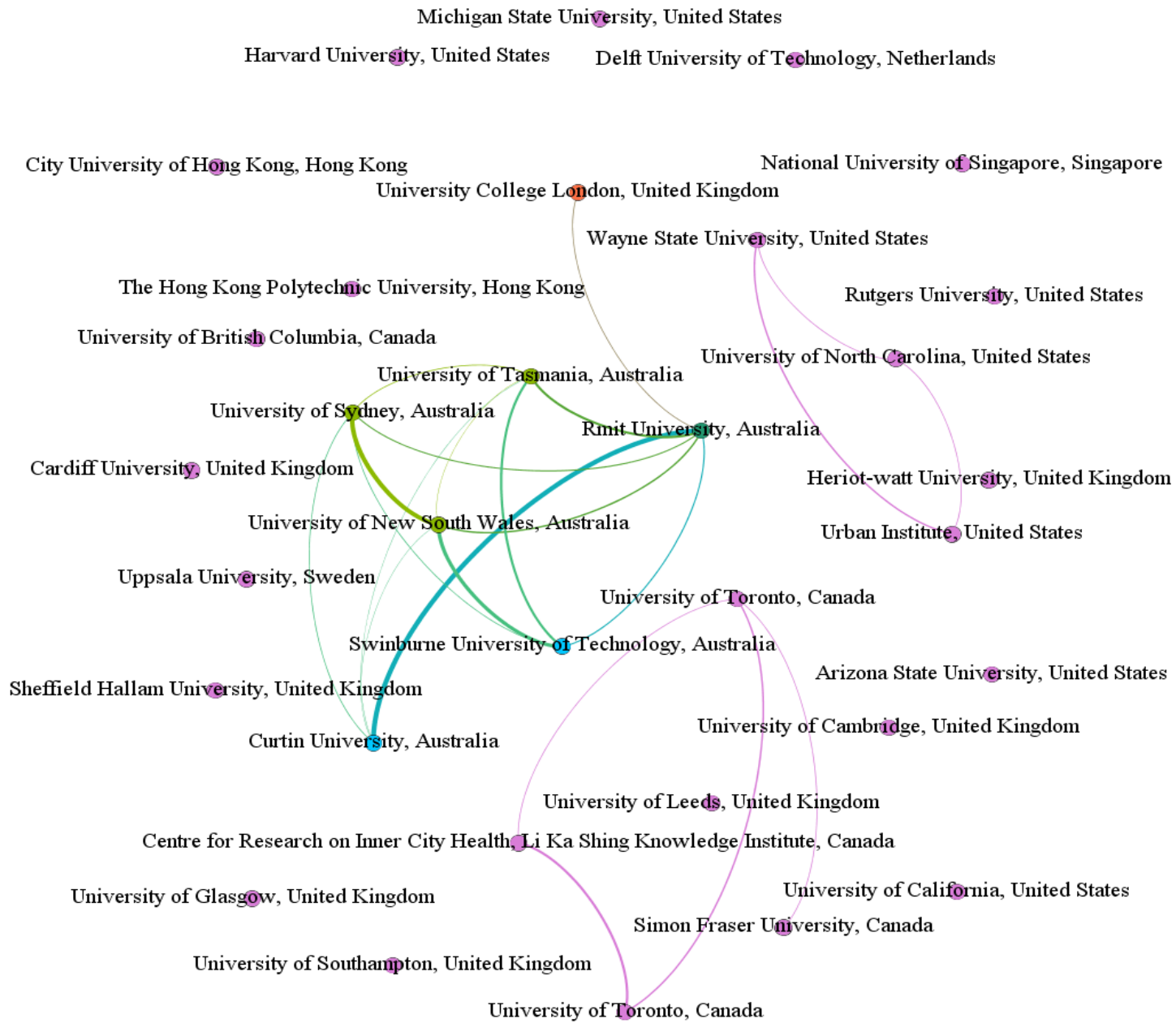







Fig. 6: Network of Collaboration among Institutions in the Housing Literature

Table 5: HUB Scores of Institutions

Hub Score	Colour Code	Proportion of Institutions with Hub Score
0.000		78.12%
0.423		9.38%
0.361		6.25%
0.093		3.12%
0.440		3.12%

The HUB score of each institution was calculated using the Gephi software. The HUB score of a node indicates the level of importance of the node in serving as key reference source to other nodes in a network (Hosseini et al., 2018). Table 5 shows the HUB scores of the institutions. From Fig. 6 and Table 5, Rmit University (Australia) had an HUB score of 0.440; University of Sydney (Australia), University of New South Wales (Australia) and University of Tasmania (Australia) had HUB score of 0.4235. Curtin University (Australia) and Swinburne University of Technology (Australia) had HUB score of 0.3607. These institutions with HUB scores above 0.20 had relatively high number of publications or documents on housing. On the collaboration pattern among these institutions (indicated by the link connecting institutions), most of the collaboration are among institutions within the same country (as shown in Fig. 6) albeit a limited number of links among institutions from different countries. According to Lu and Feng (2009), it is a common trait that most social networks have a community structure, with stronger collaboration among institutions in the same community than with those outside the community / country.

It is intriguing to note that most of the institutions from developing countries did not meet the selection criteria due to their relatively low number of documents. Thus, institutions / universities from developing countries were underrepresented in the institutional network (as shown in Fig. 6). Accordingly, the institutional network analysis further buttresses the earlier assertion that most of the international collaboration are among developed countries. The lack of international collaboration between institution of developed and developing countries could be attributed to the peculiarities of the housing issues of each country. Notwithstanding the idiosyncrasies of the housing issues, there are still similar goals or aims that most countries seek to attain in housing supply. For instance, unaffordable housing price, increasing greenhouse gas emission and energy crisis are

global crises. Therefore, collaboration at the international and interinstitutional level could enhance the implementation and adoption of technologies or policies that are holistic for sustainable housing. Policies that encourage partnering among institutions / universities on housing research could encourage efficient knowledge exchange on housing policies. To foster effective institutional collaboration for scholarly communication on the global unaffordable housing crisis, the cultural differences among countries on households' residential needs ought to be addressed.

3.5 Journal Co-Citation Network

Journal co-citation network analysis is very germane in contributing to any research discipline. It offers information on the main publishing outlets, which could aid researchers to identify quality publications to carry out any research activity. It also provides feedback to publishers and journal editors for performance assessment of their journals for improvement (Wing, 1997). Institutions such as libraries and departments of universities also need this type of information to identify quality journals, which could inform their subscription for journals (Guidry et al., 2004). Therefore, a co-citation network of journals was generated by first using VOSviewer. In creating the network, the analysis type chosen was "citation" and the unit of analysis selected was "sources". The 'minimum number of documents of a source' and 'the minimum number of citations of a source' were both set at 60 for obtaining an optimum network of journal co-citation. Of the 160 sources, 56 met the thresholds.

The generated network from VOSviewer was then imported into another networking tool Gephi for final visualization (as shown in Fig. 7). In Gephi, the weighted degree of each node was used for resizing each node. Weighted degree is modified form of the degree centrality. In network analysis, it takes into consideration the average mean of the sum of the weights of the relations / links among all the nodes in a network (Darko et al., 2020, p.9). It is used for assessing the level of influence of nodes in the control of information flow among nodes. Nodes that have higher weighted degrees have larger node sizes (as shown in Fig. 7). Table 6 shows the top 30 publication outlets that are ranked based on their weighted degree. The table also includes the weights or documents per each journal or publication outlet. Findings of the study revealed that the most prominent research outlets in the housing literature include Housing Studies, Urban Studies, Habitat International, Housing Policy Debate, Environment and Planning a, Journal of Housing and the Built Environment, Cities and International Journal of Urban and Regional Research. Moreover, the relatively high number of publications / documents from these journals shows that they are the most contributors to the housing literature.

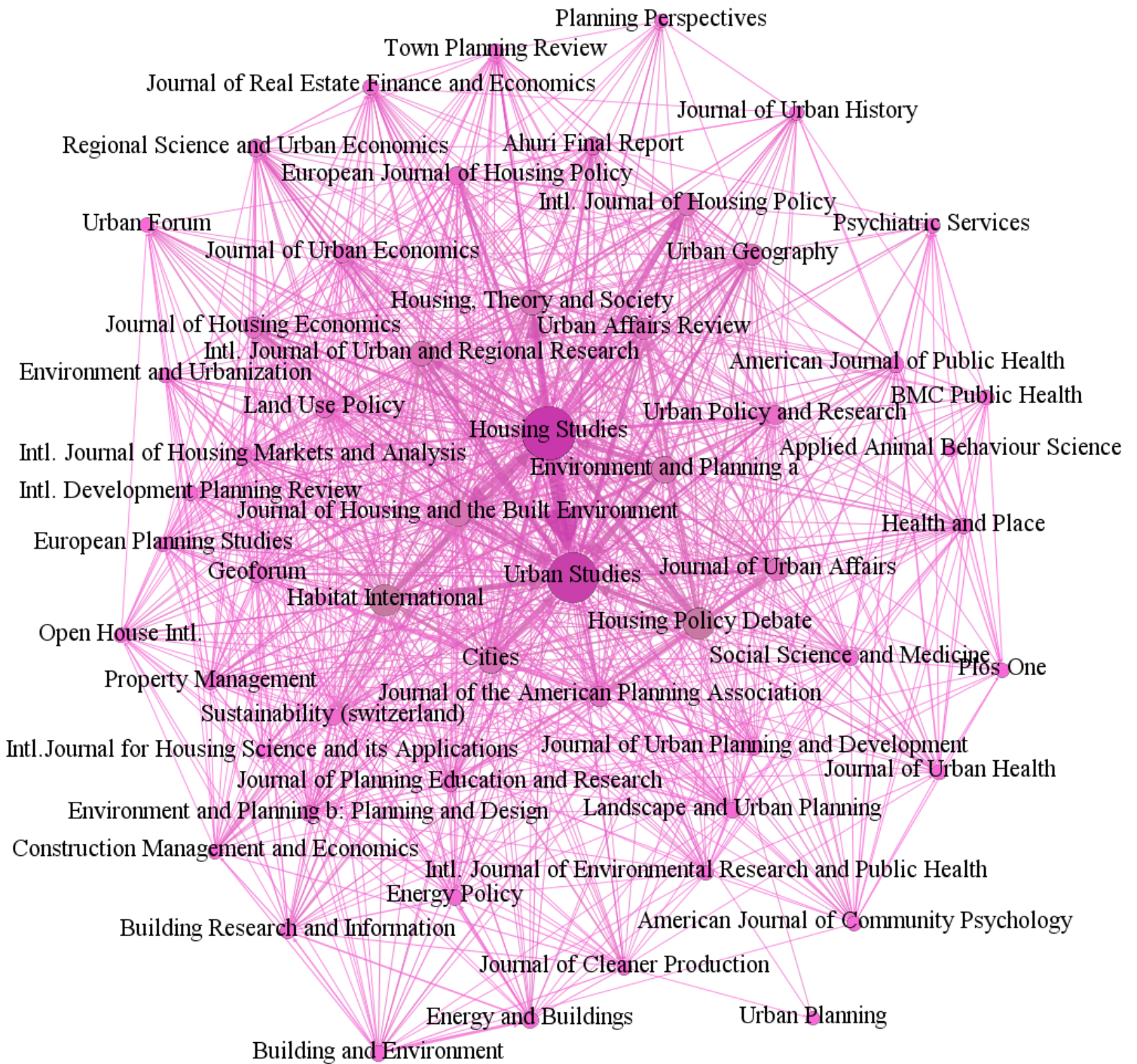


Fig. 7: Co-Citation Network of Publication Outlets / Journals

Table 6: Publication Outlets / Journals in the Housing Literature

Outlets	Documents	Weighted Degree	Ranks
Housing Studies	648	4296	1
Urban Studies	640	3992	2
Habitat International	455	1979	3
Housing Policy Debate	345	1914	4
Environment and Planning a	221	1384	5
Journal of Housing and the Built Environment	289	1344	6
Cities	282	1247	7
International Journal of Urban and Regional Research	190	1167	8
Housing, Theory and Society	210	1158	9
Journal of Urban Affairs	163	949	10
International Journal of Housing Policy	137	910	11
Urban Affairs Review	114	875	12
Urban Geography	186	828	13
Journal of Housing Economics	125	744	14
Journal of the American Planning Association	109	702	15
Urban Policy and Research	133	640	16
Journal of Urban Economics	95	574	17
Land Use Policy	123	490	18
European Journal of Housing Policy	87	486	19
Ahuri Final Report	98	448	20
Regional Science and Urban Economics	125	425	21
Sustainability (switzerland)	145	421	22
International Journal of Housing Markets and Analysis	126	394	23
Journal of Planning Education and Research	85	379	24
Geoforum	75	373	25
American Journal of Public Health	109	308	26
Energy and Buildings	232	303	27
Building and Environment	154	275	28
Journal of Real Estate Finance and Economics	61	252	29
Energy Policy	107	237	30

4. Conclusions

This study proffered a quantitative review of extant housing affordability literature through a scientometric analysis. Bibliographic data of journal articles published within two decades (1998-2017, inclusive) were downloaded using the Scopus search engine. Tools such as CiteSpace, VOSviewer and Gephi were employed in network analyses of keywords. Besides, network analyses of countries and institutions were conducted to investigate the contribution to knowledge of the housing affordability literature at the macro and micro level, respectively. Finally, the contribution of publication outlets to the

literature was analysed. Essentially, these network analyses revealed the knowledge structure and scholarly communication with regard to journal papers on housing affordability.

Results of the keyword analyses revealed that ‘poverty’ is the most influential factor in the housing affordability literature. However, underrepresented yet relevant research areas identified through the keywords analysis include: ‘cooperative housing or collective self-build housing’, ‘eco-villages’, ‘modular housings’, ‘prefabricated housing’, ‘circular economy’, ‘artificial intelligence’ and ‘water management’. These research topics did not co-occur with any of the keywords deployed in the literature search. This could be attributed to their low uptake and low research outputs concerning housing affordability. Keyword citation burst analysis showed that the trending research areas in the literature are ‘retrofitting’, ‘very elderly or vulnerable population’, ‘emission control’, ‘energy efficiency’, ‘health policy’ and ‘life cycle analysis’. Moreover, through keyword cluster analysis, the literature was summarised into four clusters, namely, ‘self-help housing’, ‘homeless adults’, ‘thermal comfort’ and ‘residential segregation’.

Network analysis of countries showed relatively high collaboration or scholarly communication among the following pairs: United States-China; United States-United Kingdom; United States-Canada; United States-Australia; United Kingdom-Netherlands; China-Australia; United Kingdom-Australia; United Kingdom-Canada. Among these pairs, only China is a developing country. One possible reason for high collaboration among these countries could be cross-country case studies and comparative studies. Similarly, findings of the institutional network analysis buttressed the findings on the international collaboration among developed countries since most of the institutions were from United States, United Kingdom, Australia, Canada and China. However, the institutional network is more of a community structure in which institutions in the same community / country collaborate more than they collaborate with institutions in other communities or countries.

This study has theoretical and practical contributions. Findings of the study indicated that for the attainment of the UN Sustainable Development Goal in housing, the most influential factor to tackle globally is poverty. Policies that mitigate income inequality and ensure income growth are essential for reducing poverty among most households. This could be achieved by providing training and development programs to enhance the technological expertise of middle- and low-income households for higher productivity attainment and for improved wages. Furthermore, incentives are required to motivate ‘cooperative housing or collective self-build housing’, ‘modular housings’, ‘prefabricated housing’, ‘circular economy’ and the application of ‘artificial intelligence’ to ensure

housing affordability universally. Moreover, research and development policies for scholarly communication or collaboration are essential among developed and developing countries and their institutions, at the macro and micro level, respectively. Such policies could enhance technology transfer / knowledge sharing for effective policies on sustainable housing.

In spite of its contributions, this study has limitations that are worth noting in the interpretation of the research findings. All network analyses on the housing affordability literature were created mainly from journal articles. Further studies could include papers from reports, books and conferences. The number of retrieved bibliometric records is restricted due to the choice of keywords. Therefore, the keywords used for conducting this study are not exhaustive.

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