Connecting the Dots between Housing Design and COVID-19

Virginia De Jorge-Huertas 1,* and Justo De Jorge-Moreno 2

1 Department of Signal and Communication Theory and Telematic and Computer Systems, Escuela de Ingeniería de Fuenlabrada, Universidad Rey Juan Carlos, 28942 Madrid, Spain
2 Economic and Business Department, University of Alcalá, 28802 Madrid, Spain; justo.dejorge@uah.es
* Correspondence: virginia.dejorge@urjc.es

Abstract: This article has aimed to analyze the intellectual structure associated with the contributions made by academics and practitioners of architecture in the association between housing and COVID-19 in the years 2019–2021. The main results reveal the possibility of establishing a classification, by topics that suggest the necessary interdisciplinary collaboration for housing, to meet the needs and desires of its users in the wake of this pandemic. The network analysis has allowed the identification of overlapping communities through interconnection concepts to other groups or clusters. Thus, it has been possible to explore the multidimensionality of the housing–COVID connection and the interrelationships for future research and its possible extension. In this sense, the importance of the specific concepts associated with very detailed elements, sensations and spaces in buildings has been identified, including concepts such as the air quality and the need for green spaces, the presence or not of balconies, the need for natural light, the existence of cross ventilation or the possibility of incorporating technology or home automation to facilitate and save resources in daily life.

Keywords: architecture design; housing; COVID-19; air quality; outdoor spaces; green spaces

1. Introduction

At the end of 2019, the coronavirus (COVID-19) appeared in a shocking and disastrous way in a very representative percentage of the world’s population. As mentioned in Ref. [1], the impact of COVID-19 poses different challenges and threats that must be considered, both those related to physical and mental health. In the first case, pandemics are recurrent phenomena throughout history, and they will be summarized below. In the second case, the threat posed by the psychological effects on people, which authors such as [2–4] among others discuss, such as destructive anxiety, stress, stigma, and xenophobia. The impact of COVID-19 on the economic sphere and all its sectors such as agriculture, health, housing, and others, is equally damaging.

Analyzing previous pandemics in a historical trip, Refs. [5–8] describe in detail the path and impact of the quarantine caused by the “Black Death” pandemic of the 14th century, cholera, the so-called “Spanish flu” in 1918–1920, SARS in 2003 or, from 2019 until 2021, the “COVID-19” (SARS-CoV-2). These authors analyze how these pandemics brought about disruptive changes in the design of architecture and cities. They encouraged a continuous interdisciplinary dialogue between architecture professionals, urban planners, and specialists in the field of health sciences, from medicine, nursing, or biology with emphasis on bacteriology and virology.

The resulting projects were, among others, the Paimio Sanatorium (1929–1933) by Alvar Aalto, Aino Marsio-Aalto, Harald Wildhagen, Erling Bjertnäs, Lauri Sipilä and Lars Wiklund, or the “Leza Sanatorium” by Pablo Zabalo in Álava (1934–1935). From the urbanistic point of view, the design of the example of the city of Barcelona by Ildefonso Cerda, in 1859, was motivated, among other issues, by the lack of habitability that produced infections and health problems to the communities. In the fields of architecture, interior design, and furniture related to the health program, the “sanatorium movement” [9]
specifically promoted the study of the sun and cross ventilation, white and smooth surfaces, light and flexible furniture, and easy to clean fabrics and skins. These are some of the design references, symbols of a common history, of how an illness can lead to design alternatives and the introduction of radical architectural spaces to the existing situation through collaboration. In the present, in the “digital age”, the rules of contagion, and their relationship with data networks, have a high impact on how and why things spread and stop [10]. In fact, the current pandemic has meant a paradigm shift in our daily lives from the domestic to the workplace and both locally and globally. A special emphasis is placed on changes in social habits, as well as on the architecture of housing and public space in cities: the changes required during the confinements caused by the different waves of contagion and the changes that have produced new situations and have affected social and working conditions. In addition, this has led to a massive abandonment of offices, occupying the home as a space for work in a virtualized remote format, challenging the reconciliation of personal life and work–life balance, as well as the challenges caused, in many cases, by a lack of support or by the absence of advance planning in terms of social services or adequate and well-structured welfare systems.

This article aims to analyze the contributions to the literature, in the architecture made by scholars and practitioners, considering the association between housing and COVID-19 in the last three years (2019–2022). In this regard, highlighting the contribution of research carried out by university professors and research institutions, through their publications, by means of the topics they address and the key words that define their work, is of great relevance for several reasons: (i) it identifies the subject to which they direct their efforts which, in principle, may imply possibilities of improvement for companies and institutions through the results they achieve; (ii) they generate a body of knowledge that advances science and transfers knowledge that could be valuable for other researchers/readers; (iii) the research activity itself provides the researcher with experience and knowledge that he/she later confers to his/her teaching or professional activity; and (iv) it allows the researcher to consolidate his/her professional career and prestige which, in turn, has repercussions for the institution to which he/she belongs.

This paper is structured as follows: after the methodology section, a first analysis maps the references, keywords, and authors working between the two concepts. In the second part, the article proposes a series of guidelines based on the previously analyzed literature review.

2. Materials and Methods

As mentioned by [11], works that conduct and evaluate a literature review, such as the present one, make it possible to identify and synthesize, in a rigorous and synthetic way, the topics analyzed and their results in order to compare them. They also identify gaps, trends, or research patterns, as well as future avenues of research. Finally, they also allow the development of new theoretical frameworks [12]. The use of social network analysis (SNA) with the type of information employed in this work has been previously used in other disciplines, such as, for example, management, marketing, entrepreneurship, and biology, among others. In architecture, Ref. [13] recently used this way of working in urban design. The literature information has been extracted through Web of Science (WoS), Scopus, and Google Scholar. The stages are shown in Figure 1: from the search for terms through the keywords (in the title or in the body of the text of the article) to the final selection, having previously chosen the architecture field.

Figure 1 shows the terms and their combinations. Specifically, and based on the above figure, articles were selected considering that they had a sufficiently explicit contribution to this connection, which also involved a qualitative analysis process. The initial database had 234 articles (134 WoS, 88 Scopus, and 12 google academic). Subsequently, duplicates were eliminated, until the final sample of 51 articles was obtained. The formation of the databases was carried out using Excel spreadsheets and from the documentation dump, as mentioned in Figure 1. For example, each key word of the selected work (in rows of
the database) was associated with its topic (in a new column). The process is detailed in Figure 2, and especially Figure 3, below. The search period was established between December 2019 and January 2021. The classification of the topics was based on text analysis by visual inspection. The word cloud tool was used to generate different clouds as shown in Figure 2.

![Figure 1](image1.png)

**Figure 1.** Stages for selecting the sample of the literature analyzed. Source: Adapted from [1].

![Figure 2](image2.png)

**Figure 2.** Word cloud of the keywords. Source: Own elaboration.

A descriptive analysis was also performed by tabulating the keywords as a categorical variable. In this case, once the classification was established, the frequency of each of the keywords in their respective classifications was determined in order to label them. The classification segments the literature into seven areas: Architecture design, Environment, Technology, Gender, Social Labor Condition, Outdoor Space, and Health and Prevention.

Figure 3 shows the main terms within each classification or topics, as a first approximation. In this sense, it is important to consider that the analysis not only considers the keywords, but also contains the abstract and the main text of the article.

As mentioned above, the methodology used was the SNA, by means of the free software Gephi, for its visual communication capacity. The previous content analysis allowed us to determine the terms or topics. Subsequently, a structural analysis was carried out, based on the links (Linkage-based) following [14]. This made it possible to determine the importance of the nodes, the links through them, and the detection of communities (or modularity). In particular, the existence of the main network and the underlying ones. The centrality measures used and performed according to the decision of the researchers and the literature allow us to interpret the connections and structure of the network.
The centrality measures used in this work are: (i) Degree centrality, which measures the number of direct connections that a node has; (ii) Closeness centrality nodes that, although they may have few connections, their edges allow the reaching of all points of the network faster than from another point. This implies the possibility of monitoring the flow of information through the network; (iii) Modularity allows the identification of communities or clusters in the network; and (iv) Betweenness centrality, which is the number of shortest paths from all vertices to all others passing through that node. The higher the value, the greater the transfer influence of a node. The measurements have been calculated by the algorithm (Force atlas2) as a function of the network structure and the position it occupies in the network. Most network programs use the layout force as directed. The underlying idea is to make the network representation as simple as possible, trying to avoid as many crossing edges as possible between nodes. In essence, as is the case with the movement of the magnet micro scale, it is a consequence of their attractive (positive/negative) [15] That is, nodes attract or repel each other depending on whether they have the same/different charge. This implies that the final network is structured in communities grouped in clusters, or communities with the appropriate structure in each case.

3. Results

This section presents the results obtained from the SNA. Sections 3.1 and 3.2 contain the results of the analysis of the classification of topics-keywords and authors-keywords.

3.1. Classification and Keywords

The SNA is performed in two complementary ways: (i) the traditional way, interpreting the representative nodes and their connections through the edges according to the chosen centrality metrics and (ii) following authors such as [16–18], it is possible to find
keywords in the network that belong to different classification topics at the same time. This way of interpreting the network offers a new vision, which allows us to understand the overlapping of communities. [18], indicate that a subdivision of a network into overlapping communities is called coverage and is referred to as soft clustering, as opposed to hard clustering, which deals with divisions into non-overlapping groups, called partitions. The generic term clustering can be used to indicate both types of subdivisions. Hedges can be crisp, when shared nodes belong to their communities with equal strength, or diffuse, when the strength of their membership may be different in different clusters.

Figure 4 shows the network structure with the seven representative nodes. By levels of centrality in order from highest to lowest, these are as follows: Architecture design, Social Labor Condition, Technology, Outdoor Space, Environment, Gender, and Health and Prevention. The nodes will be discussed individually below. As can be seen, each of the nodes is part of a network community or cluster.

![Classification Network and Keywords](image)

**Figure 4.** Classification Network and Keywords. Source: Own elaboration.

The central edges are connected through the nodes belonging to different communities. The edges have different thicknesses to show the levels of intensity of the connection. Figure 5 captures the nodes that are protagonists of the interconnections, while Table 1, collects the centrality measures.

As can be seen, air quality and green space are the most representative concepts in terms of Degree. In the case of green space, the values of Closeness and especially Betweenness are the highest, indicating the influence and connectivity between the seven topics generated. Housing design also maintains high values of these measures. In addition, the thickness of its edge in the connection with the topics Architecture design shows its relevance as being within the same region as air quality. The interconnections maintained through the concepts in Table 1 could indicate the trends in architecture design and the internal configuration of housing after the COVID-19 pandemic. The keywords extracted from the literature review underline the need to include both shared spaces and those outdoor spaces that serve as intermediaries between public and properly private space. It is important to value both the size of the architectural space and the intangible factors...
associated with internal, thermal, and perceptual comfort, including the possibility of having views. In the mapping, the importance of having balconies and spaces linked to nature, to strengthen mental health and reduce the isolation caused by certain designs, emerges, rethinking working conditions and promoting the hybridization of programs in the same architectural space.

Figure 5. Network of nodes belonging to different communities. Source: Own elaboration.

Table 1. Measures of centrality of the interconnecting nodes. Source: Own elaboration.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Degree</th>
<th>Modularity</th>
<th>Closeness</th>
<th>Betweenness</th>
</tr>
</thead>
<tbody>
<tr>
<td>air quality</td>
<td>7</td>
<td>0</td>
<td>0.53</td>
<td>20.45</td>
</tr>
<tr>
<td>green space</td>
<td>7</td>
<td>2</td>
<td>0.54</td>
<td>30.88</td>
</tr>
<tr>
<td>lookdown</td>
<td>6</td>
<td>1</td>
<td>0.53</td>
<td>21.15</td>
</tr>
<tr>
<td>housing design</td>
<td>6</td>
<td>0</td>
<td>0.53</td>
<td>22.64</td>
</tr>
<tr>
<td>adaptative architecture</td>
<td>5</td>
<td>0</td>
<td>0.50</td>
<td>13.36</td>
</tr>
<tr>
<td>sustainable architecture</td>
<td>5</td>
<td>2</td>
<td>0.47</td>
<td>11.63</td>
</tr>
<tr>
<td>housing automation</td>
<td>5</td>
<td>2</td>
<td>0.51</td>
<td>14.79</td>
</tr>
<tr>
<td>mental health</td>
<td>5</td>
<td>6</td>
<td>0.51</td>
<td>16.88</td>
</tr>
<tr>
<td>teleworking</td>
<td>5</td>
<td>0</td>
<td>0.47</td>
<td>11.63</td>
</tr>
<tr>
<td>common space</td>
<td>5</td>
<td>0</td>
<td>0.51</td>
<td>14.55</td>
</tr>
<tr>
<td>public housing</td>
<td>4</td>
<td>1</td>
<td>0.45</td>
<td>9.07</td>
</tr>
<tr>
<td>biophilic design</td>
<td>4</td>
<td>2</td>
<td>0.49</td>
<td>10.44</td>
</tr>
<tr>
<td>spatial size</td>
<td>4</td>
<td>3</td>
<td>0.49</td>
<td>9.19</td>
</tr>
<tr>
<td>natural light</td>
<td>4</td>
<td>3</td>
<td>0.47</td>
<td>8.22</td>
</tr>
<tr>
<td>respiratory illness</td>
<td>4</td>
<td>5</td>
<td>0.47</td>
<td>8.57</td>
</tr>
<tr>
<td>dwelling comfort</td>
<td>4</td>
<td>0</td>
<td>0.50</td>
<td>9.69</td>
</tr>
<tr>
<td>everyday life</td>
<td>4</td>
<td>5</td>
<td>0.48</td>
<td>8.41</td>
</tr>
<tr>
<td>flexible housing</td>
<td>3</td>
<td>4</td>
<td>0.46</td>
<td>4.68</td>
</tr>
</tbody>
</table>

The disaggregated analysis through the topics was mentioned previously in the section on data and methodology. Some of the labels could be renamed to seek greater similarity between the initial approach and the results presented below. However, it has been preferred to keep this designation, given that, in this way, it is possible to have a more
approximate idea of the ways of interpreting the different approaches to the chosen topic. In addition, it is important to consider the interconnections between the topics, from the interconnection of the nodes, presented in Figure 5. For example, housing design has a strong representation in Architecture design or Gender and, to a lesser extent, in the rest of the topics.

3.1.1. Architecture Design

Figure 6 shows the nodes related to the topic “Architecture Design”. The inclusion of vegetable gardens in housing complexes [19], the quality of views or the outlook towards greenery [20,21], as well as outdoor spaces or cross ventilation, are project decisions that seem to be reiterated. Simultaneously, modularity, flexibility, or modular distribution [22–24] are repeated as strategies to create spaces that allow for multifunction, as well as multipurpose, rooms. Passive strategies or energy control through regulating technologies are also key protagonists, including the inclusion of local materials and user experience in the project process [25]. On the other hand, “transparency” re-emerges in recent research associated with the prevention of contagion; transparency in this case is analyzed as a barrier that allows a certain interaction associated with the building’s view. In addition, the need for comfort in housing is reiterated, encompassing terms and contents such as thermal comfort, comfortable living space, and environmental comfort.

Figure 6. Topic Architectural Design. Source: Own elaboration.

3.1.2. Environment

Figure 7 shows the nodes related to the topic “Environment”. Similarly, housing in relation to the environment has multiple approaches, from resource management to its impact on the environment [26–28]. In addition, the underlying concepts linked to facilities such as consumption patterns, energy saving, renewable energies, and the need to incorporate the greenhouse strategy or water management, are included. Likewise, in response to climate variability from extreme temperatures, biophilic urbanism [29] emerges as a strategy to face uncontrolled and unplanned urban growth, as well as the need to focus on reducing the isolation of rural areas, relationships with nature or the connection with environmental sciences.
3.1.3. Gender

Figure 8 shows the nodes related to the topic “Gender”. The pandemic and the various lockdowns have caused collateral damage including “the shadow pandemic” [30–32]. This damage has accentuated the problems of domestic gendered violence and the precarious situation of women in the often unpaid and invisible work of care [33,34]. In the literature, some authors give the nomenclature “domestic violence” the same characteristics that others give to “gender-based violence” [35]. These terms have been equated in our analysis.

3.1.4. Health and Prevention

Figure 9 shows the nodes related to the topic “Health and Prevention”. The users of inhabited dwellings have suffered the consequences of the lack of adequate design of residential architecture [36,37] leading, in turn, to the social isolation caused by the pandemic. Additionally, they have suffered an outdated design in relation to fundamental immaterial parameters such as air quality [38,39], ecology principles, cross ventilation, entry of natural light, and the possibility of having green spaces and healthy spaces, in a wide range that produces an impact on the mental health [40] of its inhabitants.
Figure 9. Topic Health and Prevention. Source: Own elaboration.

3.1.5. Outdoor Spaces

Figure 10 shows the nodes related to the topic “Outdoor Spaces”. In relation to this, the connections emerged show a double path: on the one hand, the path related to the problems caused by the lack of physical interaction and the exception mechanisms applied in outdoor spaces [41–47]; and on the other hand, some questions emerge regarding the need for vital neighborhoods that encourage face-to-face interactions through gardens, courtyards, humanized streets, and dynamic public squares. Thus, this enables a regulatory framework that promotes outdoor spaces for daily life between the privacy of the home and the practices of everyday life.

Figure 10. Topic Outdoor Spaces. Source: Own elaboration.

3.1.6. Social Labor Conditions

Figure 11 shows the nodes related to the topic “Social labor conditions”. Remote labor conditions, also called “Smart working”, “Teleworking”, “Working from Home”, “Homeworking” or “Worsening of working performance”, have provoked a change in direction in how work is produced, and the role that technology plays in this, such as through emerging IT disciplines and communication networks. Precariousness, behaviors
associated with lockdown, change in routines, and vulnerability due to lack of resources and planning [48,49] emerge equally. In addition, the literature discusses the negative side of globalization associated with the spread of diseases and contagions [50].

![Diagram of Social Labor Conditions](image1)

**Figure 11.** Topic Social labor conditions. Source: Own elaboration.

### 3.1.7. Technology

Figure 12 shows the nodes related to the topics “Technology”. In relation to this, fuzzy boundaries continue to open at the intersection between physical space, remote services [51], and intangible or virtual space [52–55]. The metaverse begins to emerge as a global concomitant with concepts linked to it from the virtual house to generative design and spatial parameterization. Workflows based on drone technologies, open access mapping or geospatial information continue to emerge as new paths. Dialogues are opened, with BIM and domotic design applied to daily life with touchless technologies and remote services causing more and more frequent migratory flows.

![Diagram of Technology](image2)

**Figure 12.** Topic Technology. Source: Own elaboration.
3.2. Authors and Keywords

Figure 13 shows the structure of the authors and keywords network. The network construction uses the same metrics as in the previous sections, specifically in terms of weights, betweenness and modularity. Despite the complex structure of the network, it is possible to appreciate the most representative nodes in keywords or authors.

![Authors' networks from the full reference list [1–57] and keywords. Source: Own elaboration.](image)

In Figure 14, the global network has been filtered according to the Betweenness measure which, as mentioned above, allows the determining of the importance or influence of the nodes in the propagation of information through the shortest paths (geodesic paths). As can be seen, housing design, air quality, and green space are the most relevant nodes.

Finally, Figure 15 shows the relationship between the most representative keywords, considering values greater than 10 in the degree measured with weights and the authors associated with them. For example, in Ref. [56], of the 10 associated keywords, the figure shows their linkage with housing design, air quality, lockdown, and mental health. For example, Ref. [57] is related to 10 keywords and, according to the filter performed, would be linked by only two: air quality and green space.
Figure 14. Keyword network according to the Betweenness measure. Source: Own elaboration.

Figure 15. Network between keywords and authors of state of the art and the reference list [1–57]. Source: Own elaboration.
4. Future Directions

Extensions of this work could be aimed at continuing research with other ways of classifying the topics, for example, applying content analysis methodologies and comparing with the classifications made for the topics. Additionally, the period of analysis could be extended, or different topics could be analyzed. Finally, the limitations of the work are related to undertaking the aforementioned extensions.

5. Conclusions

This article has analyzed the intellectual structure associated with the contributions made by academics and practitioners of architecture in the association between housing and COVID-19 in the last two years (2019–2022). The main results reveal that the classification performed suggests that disciplines such as architecture design, environment, medicine, psychology, and landscape architecture come together, indicating the necessary interdisciplinary collaboration for housing to meet the needs and desires of its users in the aftermath of this pandemic. The identification of interconnection nodes to different communities suggests the importance of specific concepts linked to very detailed elements, sensations and spaces of the buildings where air quality and the need for green spaces are factors to consider; for example, the presence or not of balconies, the basic need to have the entry of natural light, the existence of cross ventilation, or the possibility of incorporating technology or home automation to facilitate and save on resources in everyday life. From the different connections of the nodes, we can appreciate the emission of signals regarding the risks caused by home isolation, the increase in violence against women in the domestic sphere, or the lack of resources dedicated to social welfare and mental health on the part of regulatory agents.

The limitations or biases of the work could be related to the doses of subjectivity that, in some cases, could be associated with the analysis process, for example, in the criterion for grouping keywords in the topics. In any case, this, and other limitations, have been attempted whenever possible; in the case mentioned above, it is attempted through word clouds. Possible extensions of this work could be related to the incorporation of new contributions to the literature review as the number of analyzed works increases, where the greater experience of the post-pandemic process will surely enrich the results.

The relationship analyzed in this study between housing and COVID-19 is part of what could be considered a complex system. The evolution of the popularity of SNA methodologies, which is a tool for trying to understand complex networks, including social, technological, or biological organisms, is unquestionable. The advance of this methodological proposal walks in parallel with the importance of studies on literature reviews, as methodologies that contribute significantly in the methodological, conceptual development, and various other fields. In this sense, a topic evolves when previous studies, which, in turn, have been based on previous findings, are synthesized and analyzed. The critical debate through systematic reviews allows the identification of gaps and theoretical support. With the SNA methodology it is possible to detect, in general and in this work in particular, the underlying structure of the existing relationships in the network to be analyzed, which is otherwise practically impossible through descriptive processes.

The possibilities provided by this type of analysis based on the SNA methodology could also serve to support the learning process of students in the different fields of architecture and in its implications with other disciplines.

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