



## Article

# Locality of Residential Areas in COVID-19 Pandemic Conditions: Analysis of Neighborhoods and Housing Design in Saudi Arabia

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**Abstract:** The current coronavirus COVID-19 pandemic is impacting countries across the world, resulting in governments undertaking a number of precautionary measures for their populations. This raises the issue of the effectiveness of urban design of dwellings to assist with these measures. This study therefore determines the current readiness of local neighborhoods and housing in Saudi Arabia to face epidemics. The study employs an analysis of a public survey achieving a comprehensive (n = 413) across the country to identify: (a) the current situation of local neighborhood and services, including density and the ability to fulfil human needs during periods of quarantine; (b) the ability of housing design to assist with social distancing; (c) appropriate housing design to fulfil social needs; and (d) the design of housing to accommodate the ability for infected household members to self-isolate. The findings identify that neighborhoods in Saudi Arabia meet current social requirements and can assist in avoiding gatherings. In addition, it illustrates the advantages and disadvantages of housing design, revealing that villas tend to be low density, and so facilitate social distancing, but neighborhoods with a high number of residential units face considerable challenges, due to the high density of population, particularly in areas lacking planning.

**Keywords:** COVID-19; quarantine house; neighborhood; housing; Saudi Arabia



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## 1. Introduction

The locality of a neighborhood is an important factor in controlling the movement of a population across a city and minimizing the need for transportation [1]. Furthermore, locality also covers the presence of vital services, avoiding the need for a population to travel outside their immediate area, including the provision of public open spaces and health services, along with mosques and shops [2,3]. Thus, the COVID-19 pandemic has proved an important test of the effectiveness of local neighborhoods, in particular the need to accommodate quarantine and self-isolation [4,5]. In Saudi Arabia, cities are planned and controlled by the Ministry of Municipality and Rural Affairs, with some towns and villages still under development. These areas contain both houses and apartment buildings in close proximity, creating high density populations, leading to challenges when facing a serious disease such as COVID-19.

Coronaviruses earn their name from the characteristic crown-like viral particles (virions) that dot their surface [6]. This family of viruses infects a wide range of vertebrates (most notably mammals and birds) and are considered a major cause of viral respiratory infections worldwide [7]. Hence, areas created under the management of a master plan for urban areas have recognized the issue of population density. They have also taken account of the fact that areas of residential units, along with local urban planning and design, can play a scientific role in facilitating quarantine and social distancing. Furthermore, although

housing design has been found to meet social needs, it does not tend to accommodate the additional requirements highlighted by the pandemic, i.e., the need for social distancing and self-isolation.

This current investigation therefore seeks to determine how Saudi housing design, along with urban and architectural systems, can meet the needs of occupants during pandemics. The study is structured as follows: (a) introduction; (b) research methodology; (c) results and analysis; (d) discussion; and (e) conclusion and recommendations as presented in flowchart below (Figure 1).

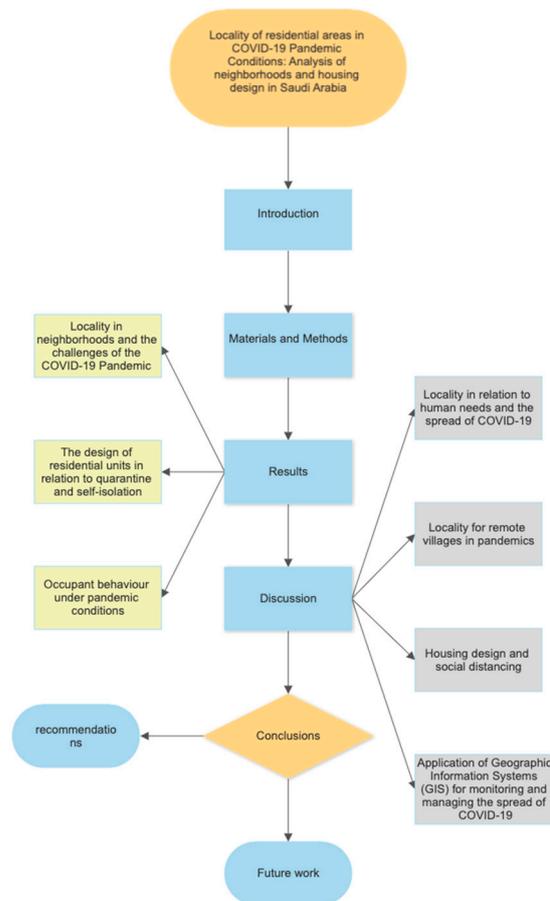


Figure 1. Flow chart for the study.

## 2. Materials and Methods

In order to determine the readiness of the current design of Saudi housing and neighborhoods to face epidemics such as COVID-19, this research employed a public survey analysis approach. There are a number of potential methods for achieving the aims of this study, i.e., questionnaires, site visits, and engineering consultation interviews. However, in order to reach a maximum number of existing residential units, the researchers employed a public survey to gather data and answer the following research questions:

- RQ1: What is the current readiness of Saudi housing to accommodate curfew and self-quarantine?
- RQ2: What is the current readiness of Saudi neighborhoods for the implementation of partial curfew and self-quarantine, in particular in relation to local services and facilities?
- RQ3: What are the challenges faced by the family members during self-isolation, when they are confined to their homes and locality within neighborhoods?

- RQ4: What do neighborhoods require in order to achieve full locality, and which is the best unit design the meet the needs of social distancing, as well as safely accommodating family members infected with COVID-19?

To answer these questions, and so achieve the aims of this study, the researchers employed a questionnaire survey [8,9], in accordance with quantitative research, analyzing the numbers gathered from the results [10]. This revealed comprehensive data related to (1) neighborhood design; (2) the availability of important facilities (i.e., public and open spaces); and (3) the design standard to allow for social distance behaviors and housing design to enable quarantine. In addition, the researchers used a pilot study [11,12] to confirm the effectiveness of the questionnaire, using samples from Saudi Arabia. Furthermore, the questionnaire was divided into three main categories to assist the researchers to analyze the findings, as follows: (a) neighborhood design and availability of urban facilities and public needs; (b) housing design and the ability to provide social distancing and self-isolation; and (c) occupant behavior under pandemic conditions. Two adult samples were used to test the validity and reliability of a revised version of Finucci's (1982) Reading History Questionnaire [13]. Due to pilot research that had been conducted to validate the questions, one of the most popular methods for gathering data, particularly in social science research, is the questionnaire. The primary goal of a questionnaire in research is to collect pertinent data in the most accurate and trustworthy way possible [14]. When choosing and conducting the right validity type to assess a research instrument (questionnaire/survey), young researchers frequently experience confusion [14].

The questionnaire was designed to highlight the views of the local population concerning the locality of neighborhoods and the design of homes. The questionnaire therefore covered four main categories. Firstly, it put forth general questions, related to the demographic details of respondents, i.e., gender, educational level, age, and geographic location. These also focused on the locality of areas and architectural design, aiming to highlight the type of accommodations available, including the number of rooms in relation to the number of family members and the effectiveness of homes during the pandemic. Secondly, it posed questions concerning the type of neighborhood, or village, as well as the availability of vital facilities during periods of quarantine, in order to highlight any weaknesses. In addition, this section analyzed the sufficiency of facilities in neighborhoods with a high-density population, along with the ability to self-isolate in flats within urban districts.

Thirdly, the questionnaire focused on the ability of housing design to safely accommodate family members testing positive for COVID-19, including comparing the number of family members to the number of rooms, and the ability of each individual residential unit to practice social distancing and self-isolation. Fourthly, the questionnaire also sought to highlight whether these residential units had been designed by an engineering consultation office and if they met the minimum architectural criteria. The study used online distribution, as this is flexible and faster, and can cover a greater number of responses across the country in comparison with a printed survey. Furthermore, online distribution is less costly and leads to a simpler analysis of the results. In order to access a large number of respondents, the researchers used SurveyMonkey ([www.surveymonkey.com](http://www.surveymonkey.com) "accessed on 22 January 2022"), with the link being distributed by means of email, WhatsApp, and various public social media channels in Saudi Arabia.

The snowball technique is a scientific method for distribution questionnaires to the public, taking advantage of the initial participants' connections and contacts. The researchers employed the snowball technique, which has been defined as chain-referral or link-tracing, encouraging participants to forward the questionnaire to others, in order to attain a high level of participation. It can be expensive and time-consuming to gather research data using conventional methods, such as face-to-face questioning, postal questionnaire distribution, or telephone surveys [15]. An additional affordable survey option that has recently emerged is the data collection approach based on "e-based and internet" technologies, such as emails and online platforms [15]. Hence, there are many methods available for questionnaire distribution, which involve designing online questionnaire links to provide flexibility in

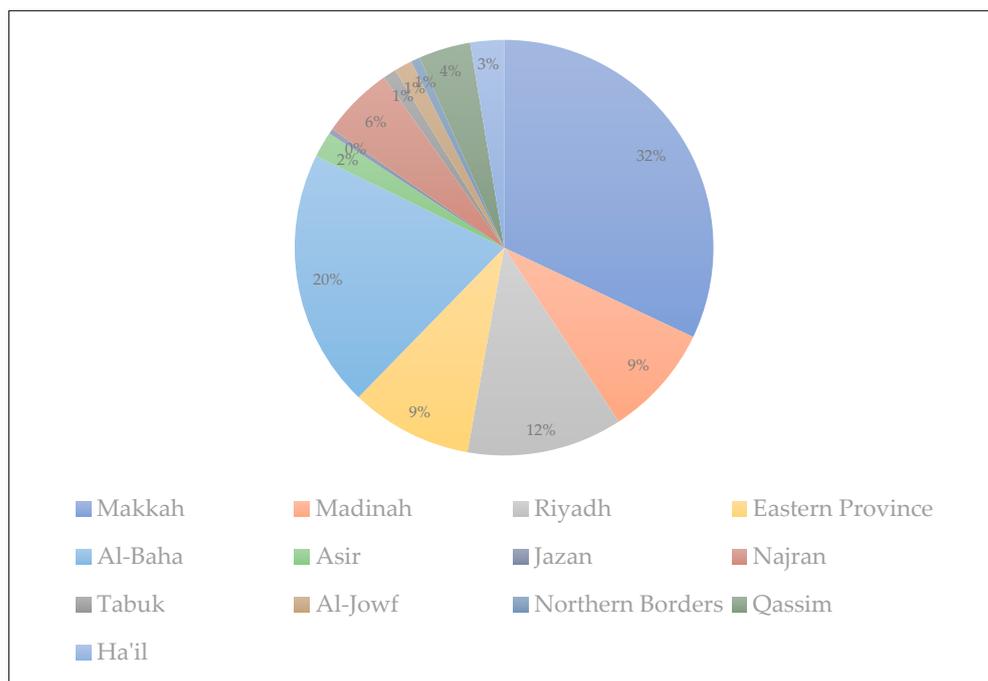
distribution. Furthermore, the analyses of the results can be easily performed after a survey has been completed and closed. It is well known that a method of survey sample selection called the “snowball sampling” technique is frequently used to identify hidden populations [16]. The advantage of the online distribution approach is its cost-effectiveness and relative efficiency [16]. This strategy depends on responders from the first sample who recommend that other people may share features of interest with them [16]. As part of this chain of referral process, known as snowball sampling, a base of initial contacts are encouraged to introduce their colleagues to the study, and they in turn suggest and recommend participation to other people [17]. This procedure is repeated until an adequate sample is achieved [17]. This will then make it possible to reach respondents in different cities, towns and villages across Saudi Arabia. This approach does, however, have some weaknesses; i.e., nonrandom selection processes, relationships between network size and selection probabilities, and privacy issues. A number of previous studies have confirmed the advantages of applying snowball sampling techniques to distribute questionnaires among respondents [18,19]. In addition, the use of a subset of a population to represent the whole is termed ‘sampling’ and can be qualitative and quantitative. The statistical quantitative sampling approach (i.e., the probability sampling technique) enables the researchers to calculate the probability of obtaining a particular sample [20,21], so overcoming any restraints of the time, cost and workforce required to gather a true random response sample to represent an entire population [22]. This approach therefore facilitates a wide range of distribution using the snowball technique and allowed the current researchers to monitor the responses and analyze the results. The distribution was repeated from March 2020 until the required number of participants had been reached.

### 3. Results

The questionnaire was distributed online across Saudi Arabia, covering all thirteen regions and participants of both genders, as well as differing ages and educational levels. The results evaluated the current condition of neighborhoods and housing units under the conditions of the COVID-19 pandemic. Table 1 below shows the demographic details of the respondents and Figure 2 shows the responds percentage according to the regions. In order to fulfil the main goal of this study and answer the research questions discussed above, the analysis focuses on two main categories, each of which presents the numerical results and highlights the condition of each locality based on the views of the respondents. Firstly, there is an examination of the views of local residents, including the level of existing services in relation to local density and whether they are capable of facilitating social distancing. Secondly, there is a discussion of the existing residential units, along with a social analysis in relation to quarantine and self-isolation.

**Table 1.** Demographic details of respondents.

Age	Percentage	Gender	Percentage	Education Level	Percentage	
12–17	0.97%	Male	74.33%	High school or less	15.98%	
18–24	10.41%			Bachelor’s degree	40.19%	
25–34	18.89%			Female	Master’s degree	15.74%
35–44	34.38%				PhD	28.09%
45–54	22.28%					
55–64	11.38%					
65 and more	1.69%					



**Figure 2.** Response percentage according to the regions.

### 3.1. Locality in Neighborhoods and the Challenges of the COVID-19 Pandemic

The survey covered a number of aspects in order to evaluate human needs within neighborhoods, reflecting the levels of locality achieved within each residential area even under the conditions of a global pandemic, including the ability to fulfil the requirement for social distancing.

- Type of neighborhoods

There are four types of neighborhoods in Saudi Arabia: (1) residential villas; (2) residential flats; (3) settlements; and (4) unplanned villages and similar areas. Figure 3 illustrates the relevant percentage of residential neighborhoods. Each form of residential neighborhood has differing services, density of population, and lifestyle. The majority include residential flats, and which generally incorporate a higher level of population, resulting in challenges in maintaining social distance, as is also the case for unplanned areas. This indicates that such areas need to focus on increasing the provision of services in accordance with the density of population rather than catchment area, in order to ensure the ability to maintain social distancing during the COVID-19 pandemic.

- Local services and social distance evaluation

The researchers considered it essential to analyze the local infrastructure of each neighborhood, in order to establish the ability of the locality to effectively support quarantine and self-solation and offer sufficient services to prevent inhabitants being forced to travel to a separate neighborhood to fulfil their essential needs. The survey covered eight aspects: (1) public parks; (2) walking pathways; (3) bicycle pathways; (4) infrastructure; (5) waste management; (6) mosques; (7) marketplaces; and (8) health care (Table 2). The survey demonstrated that the majority of these are available in most neighborhoods and are of high quality, as reflected in Figure 4.

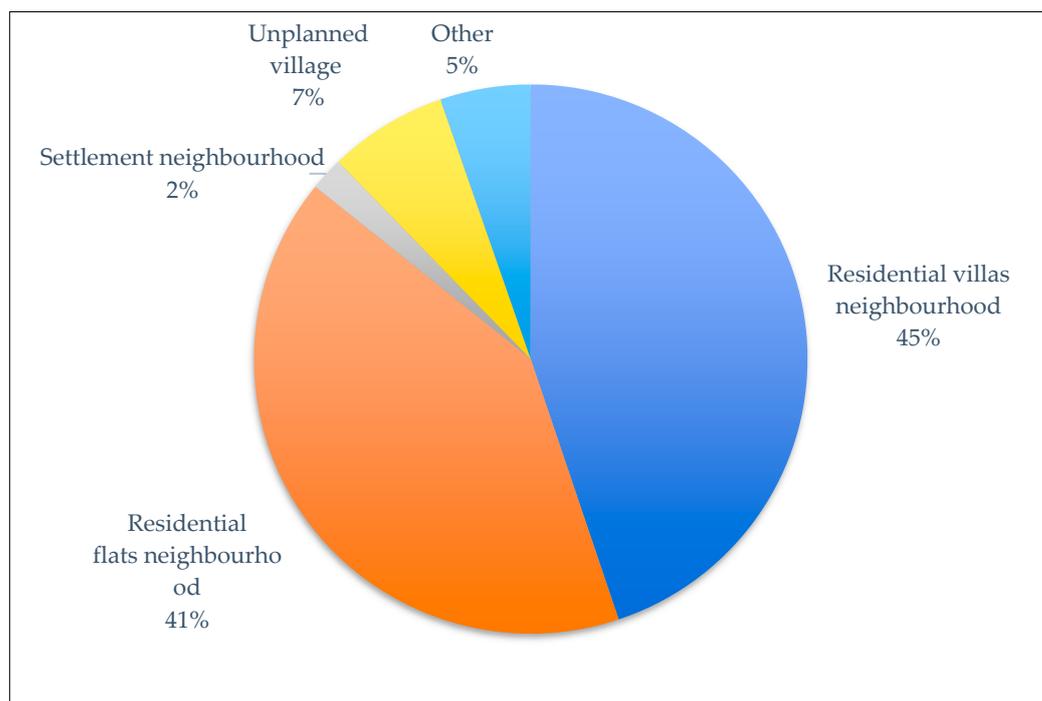
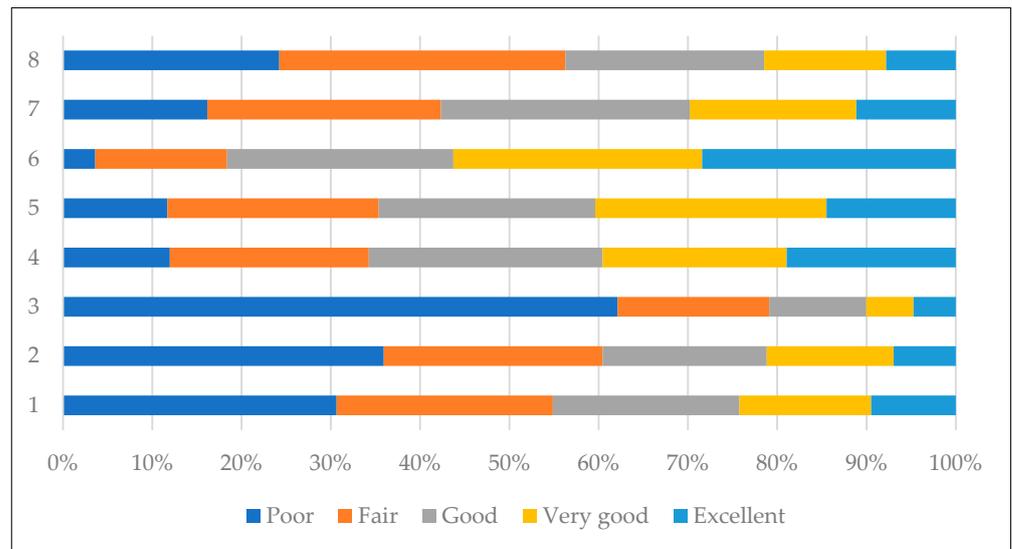


Figure 3. Types of neighborhoods.

Table 2. Evaluation of the urban planning of the residential neighborhood.

	Description	Poor	Fair	Good	Very Good	Excellent
1	Availability and appropriateness of public parks (for physical spacing) and afforestation within the neighborhood.	30.64	24.23	20.89	14.76	9.47
2	Availability and appropriateness of the width and suitability of pathways for physical spacing within the neighborhood.	35.93	24.51	18.38	14.21	6.96
3	Availability and appropriateness of bicycle pathways in the neighborhood.	62.12	16.99	10.86	5.29	4.74
4	Availability of infrastructure services, including electricity, sanitation, and sewerage system within the neighborhood.	11.98	22.28	26.18	20.61	18.94
5	Availability and suitability of waste management services within the neighborhood.	11.7	23.68	24.23	25.91	14.48
6	Availability and suitability of mosques within the neighborhood.	3.62	14.76	25.35	27.86	28.41
7	The availability and suitability of marketplaces within the neighborhood.	16.16	26.18	27.86	18.66	11.14
8	The availability and suitability of healthcare facilities within the neighborhood.	24.23	32.03	22.28	13.65	7.8

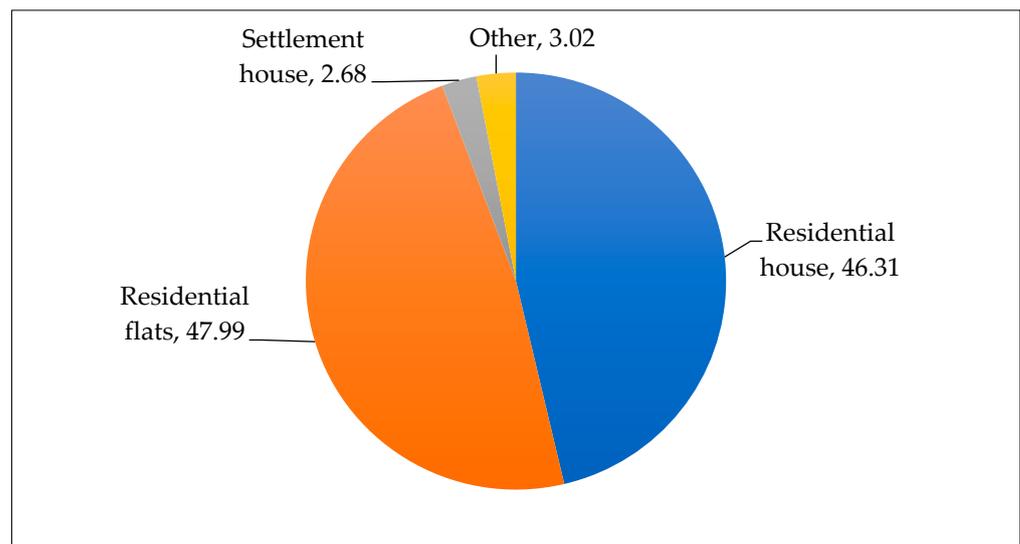
However, a number were found to be in poor condition, resulting in inhabitants needing to travel to meet their essential needs, resulting in difficulties in the face of the restrictions due to COVID-19. This included bicycle tracks, with over 60% of respondents stating that these were in a poor condition, indicating that future urban design should consider the need to ensure the provision of good quality pathways for physical spacing and bicycle tracks. However, the respondents considered other essential facilities (i.e., mosques and marketplaces) to be of high quality and capable of ensuring local self-sufficiency, thus helping to slow the spread of the virus by ensuring the needs of residents can be met.



**Figure 4.** The level of quality of local services in the residential neighborhoods.

*3.2. The Design of Residential Units in Relation to Quarantine and Self-Isolation*

The study considers that it is vital that the design of each housing unit offers the occupiers privacy, particularly when it comes to the need for quarantine and self-isolation. The study examined the area of accommodation in relation to the requirements for self-isolation to slow the spread of COVID-19. Figure 5 demonstrates the types of accommodation recorded by the respondents. In addition, the participants were requested to indicate the number of residential units within each building, in order to establish the density of occupants per square meter, and so evaluate the risks in relation to cases of COVID-19, as shown in Figure 6. This reveals that there are between three and ten units in the majority of buildings, due to these being apartments containing many individual families, who also share some facilities. This indicates the need for additional areas to be available for any individual testing positive for COVID-19 to self-isolate, while at the same time ensuring minimum risk for other family members.



**Figure 5.** Types of accommodation reported by the respondents.

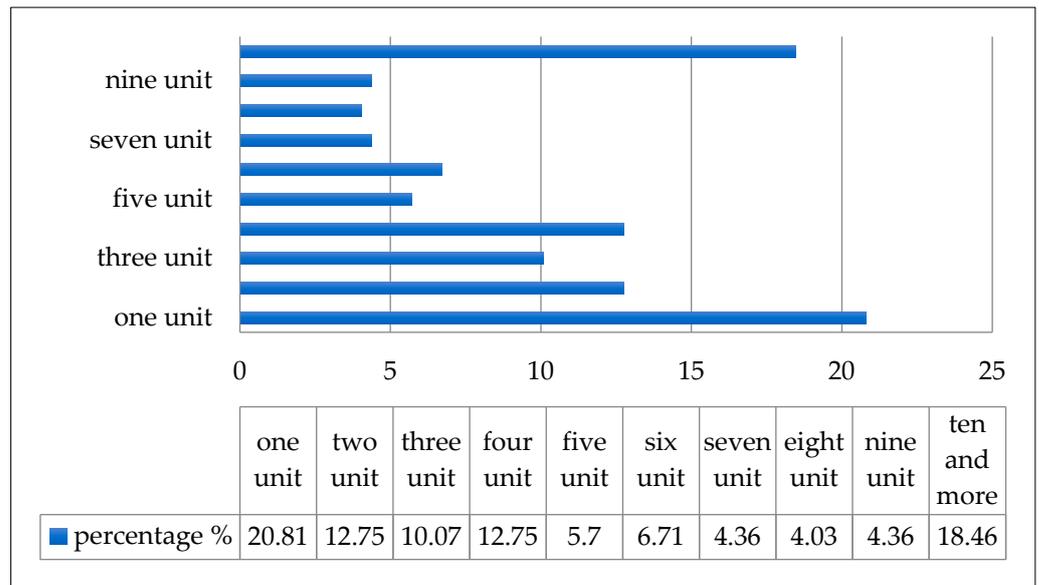


Figure 6. Number of residential units within each building.

The questionnaire sought to determine the number of family members per unit, in order to evaluate the potential for self-isolation without risk to others, as shown in Figure 7. This demonstrates a high density of occupants per residential unit, resulting in considerable risk should one family member become infected with COVID-19. In addition, the area and internal design of the unit could play a significant role in minimizing this risk, however, this requires individual analysis of each design. The questionnaire also asked participants to note the number of rooms in each unit, in relation to the average size of family, and which varied according to type and area of the unit, as shown in Figure 8.

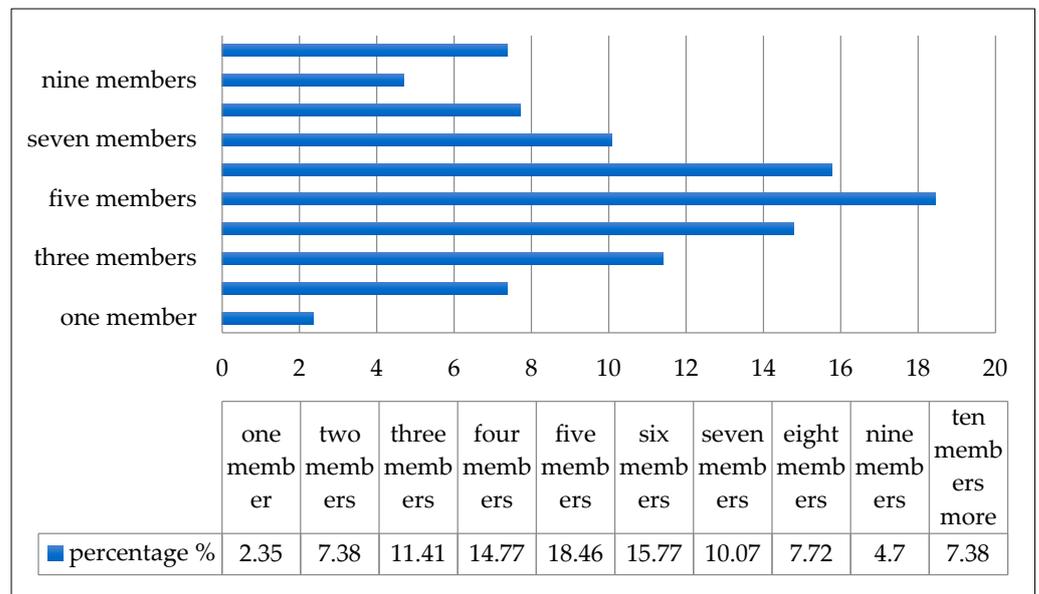
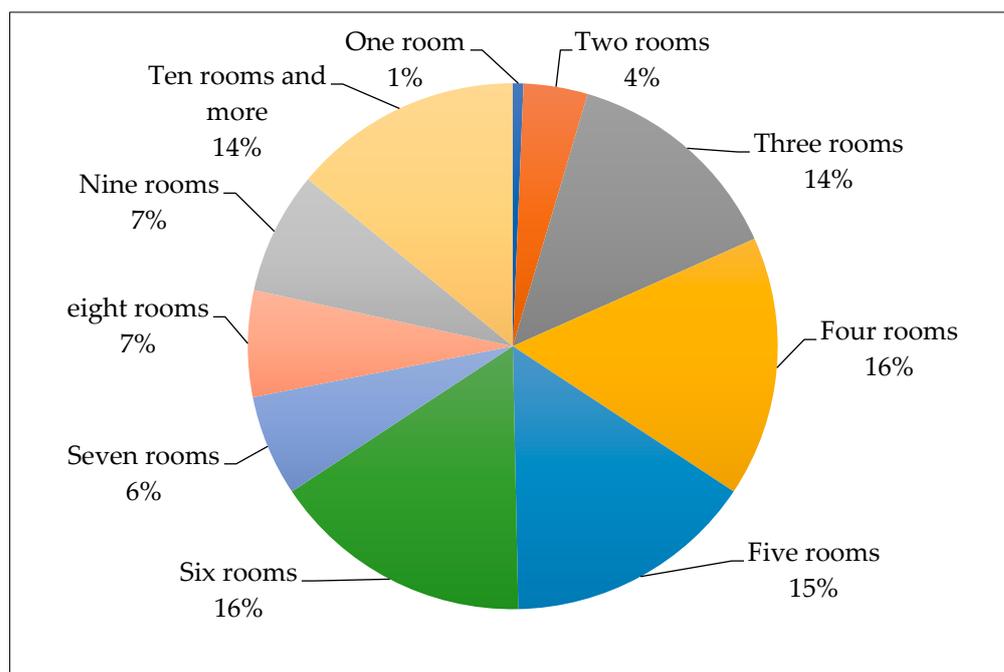


Figure 7. Number of family members in residential units.



**Figure 8.** The number of rooms in each residential unit.

### 3.3. Occupant Behaviour under Pandemic Conditions

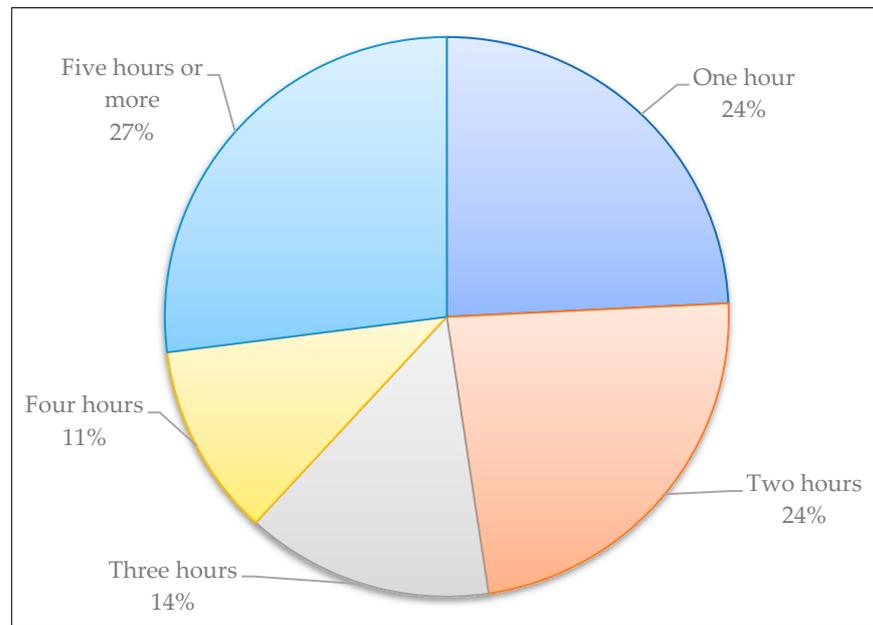
The study also analyzed the behaviors of the occupants, along with the ability of the residential designs to meet the need for social distancing and self-isolation in the event of positive cases of COVID-19. This included direct questions to respondents, as well as their user profile in terms of each unit.

- Occupant behaviors

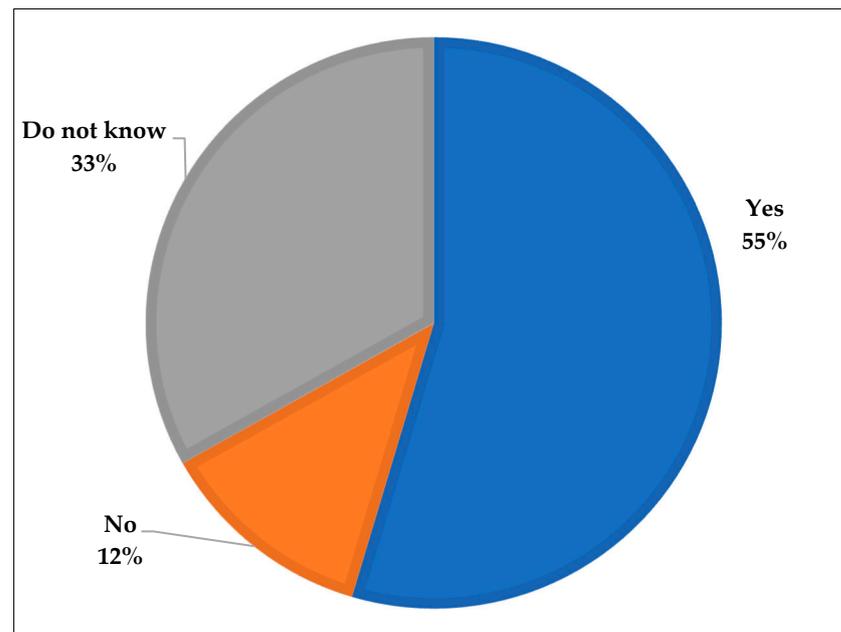
It has been previously established that the routine behavior of occupants plays a significant role in the spread of COVID-19, both within and outside a property, and between family members. Figure 9 presents occupant behavior during the pandemic, reflecting the risk faced by each family member as a result of community contact, both in relation to work and external activities. This reveals that that approximately 27% of families spent five hours outside the home, as well as their time at work, and so highlighting the high risk of transmission posed by the virus. Furthermore, Figure 9 illustrates that about 25% of respondents spent between three and four hours outside the home for social activities, as well as for the provision of essential needs. It is important to note that around 24% of respondents stated that they spent only one hour or less outside the home, which was determined as focusing on acquiring daily essential needs.

- Home design

This study established whether the accommodation was modern, was designed by a qualified specialist, and whether it offered the minimum criteria of architectural features. Some of the residential units were found to have been built by a developer, while others were modern units designed by an engineering consultation office applying the appropriate architectural criteria. Figure 10 displays the house design method as indicated by the respondents. This demonstrates that the majority of residential units were designed by a specialist engineering consultation office, which applied architectural design criteria and fulfilled the needs of the occupants. Furthermore, approximately 33% of the respondents highlighted that they are not certain if their homes had been designed in this way, while 12% confirmed that this was not the case.



**Figure 9.** Number of hours spending outside home exclusive of working time.

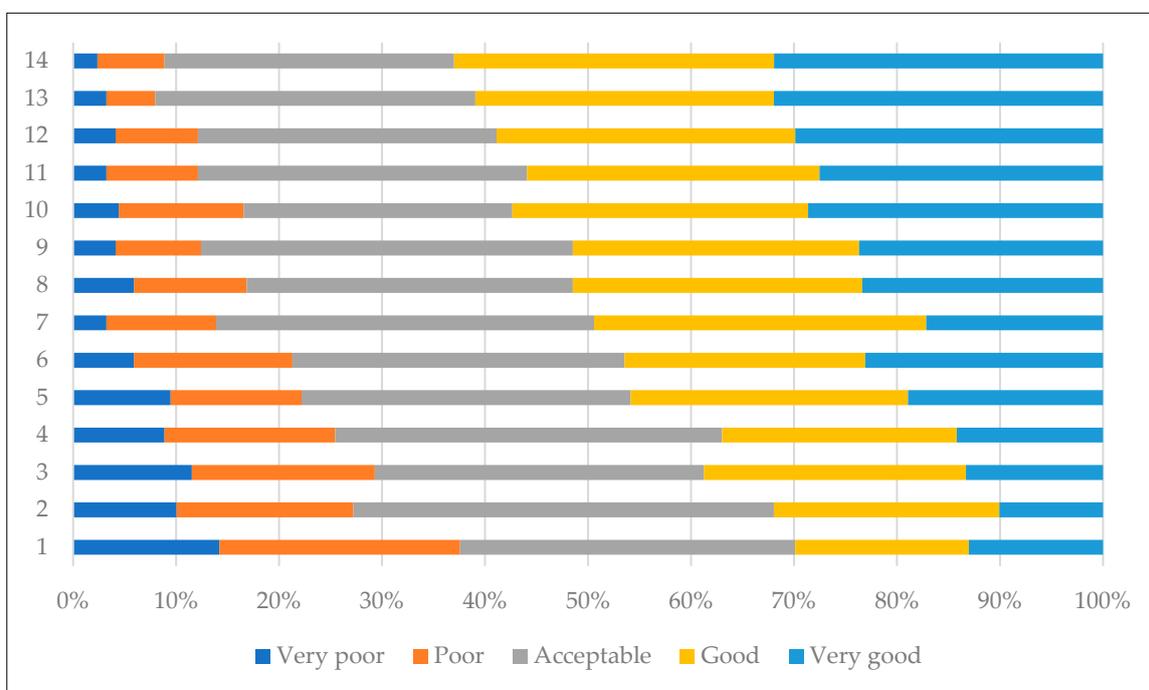


**Figure 10.** Percentage of housing designed by an engineering consultation office.

Architectural design is required to meet a considerable number of criteria, including: (1) the quality of exterior yards and gardens; (2) shade distribution around the building; (3) insulation and acoustic privacy within the home; (4) the availability of natural lighting; and (5) sufficient rooms in each residential unit to allow individuals to quarantine. These dimensions were examined in the survey in order to establish the occupants’ satisfaction with their homes, including in relation to the ability to self-isolate. Table 3 reflects fourteen dimensions focusing on the quality of architectural design from the perspective of the residents. It is notable that the possibility for ensuring sufficient rooms for individual self-isolation is shown as 32.25% being acceptable, 23.37% as good, and 23.08% as very good (Figure 11).

**Table 3.** The participants’ views of the quality of architectural design.

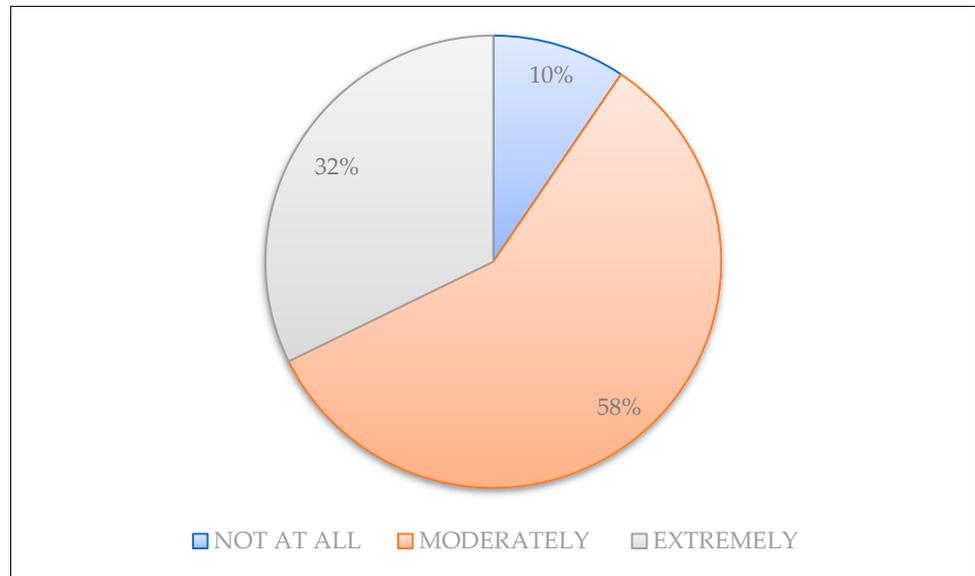
	Description	Very Poor	Poor	Acceptable	Good	Very Good
1	Quality of exterior yards and gardens.	14.2	23.37	32.54	16.86	13.02
2	Satisfaction with shade distribution around the building.	10.06	17.16	40.83	21.89	10.06
3	Satisfaction with acoustical insulation and acoustic privacy at home.	11.54	17.75	31.95	25.44	13.31
4	Satisfaction with the electricity consumption under the practice of complete quarantine.	8.88	16.57	37.57	22.78	14.2
5	Quality of exploitation of natural lighting.	9.47	12.72	31.95	26.92	18.93
6	Satisfaction with the possibility of arranging rooms in the residential unit to facilitate quarantine for each individual independently.	5.92	15.38	32.25	23.37	23.08
7	Satisfaction with the temperature and humidity inside the residential unit.	3.25	10.65	36.69	32.25	17.16
8	Satisfaction with the home design to practice a quarantine for the family	5.92	10.95	31.66	28.11	23.36
9	Quality of architectural design and spaces distribution and exploiting spaces in the residential unit	4.14	8.28	36.09	27.81	23.67
10	Quality of plumbing installation in the building.	4.44	12.13	26.04	28.7	28.6
11	Quality of lighting distribution and electrical installation in the residential unit.	3.25	8.88	31.95	28.4	27.51
12	Quality of natural ventilation and distribution of windows for the residential unit.	4.14	7.99	28.99	28.99	29.88
13	Satisfaction with spaces and area within the residential unit.	3.25	4.73	31.07	28.99	31.95
14	Satisfaction with the social and visual privacy within the residential unit.	2.37	6.51	28.11	31.07	31.94



**Figure 11.** The participants’ views of the sufficient rooms for individual self-isolation.

This study examined whether each unit had been architecturally designed to provide sufficient social and psychological comfort, particularly when it came to the need for self-isolation at home to prevent the spread of the virus. It has previously been established that

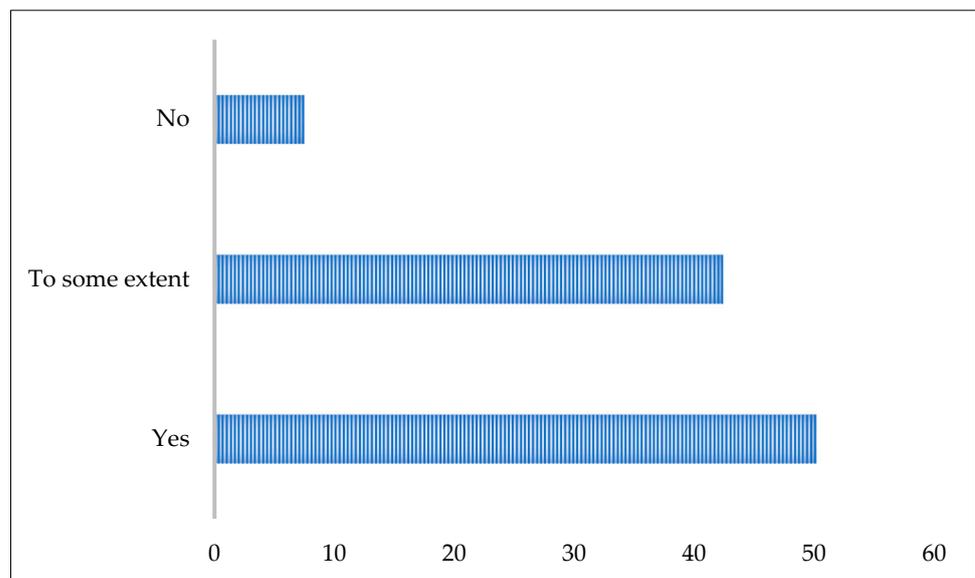
some designs may require retrofitting to achieve this aim. The results as demonstrated in Figure 12 show approximately 58% of homes rated as offering moderate comfort, while 10% were found to offer insufficient psychological comfort during periods of quarantine, although approximately 32% of home designs were found to provide adequate psychological comfort.



**Figure 12.** The ability of architectural design to provide social and psychological comfort.

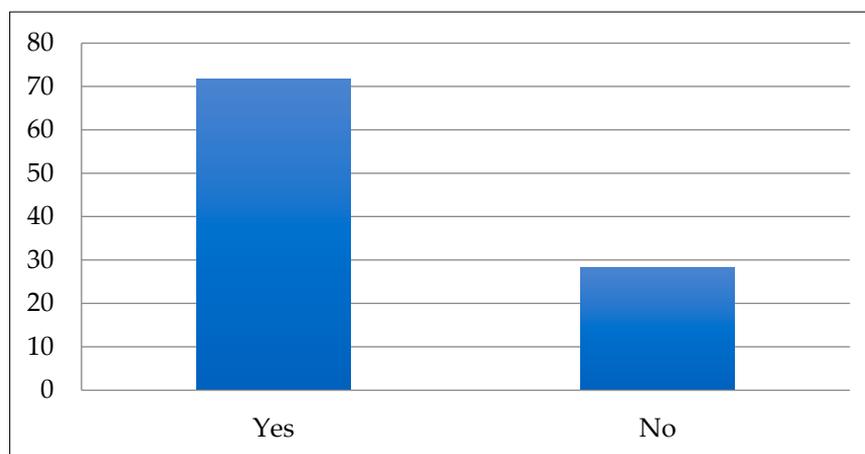
- Ability of practicing social distance and self-isolation

This study focused on ability of the design of residential units to provide sufficient physical or social spacing in relation to the current COVID-19 pandemic. Figure 13 shows the ability of the residential units surveyed to provide social distancing, reflecting the use of space in relation to the size of each family, particularly in order to avoid the risk of spreading COVID-19 among family members. The research found that the majority of homes facilitated the practicing of social distancing, while over 40% were able to practice some degree of safety procedures when it came to the need to socially distance from other family members.



**Figure 13.** The ability of residential unit to facilitate social distancing.

However, it is also clear that the number of rooms tend to vary in accordance with the number of family members, which can be over seven and therefore need additional space. This demonstrates that each family member must evaluate their needs in relation to the size of the family and number of rooms, in order to establish their ability to self-isolate at home. The questionnaire offered the respondents the opportunity to express their views concerning this issue, as shown in Figure 14.



**Figure 14.** Contribution of domestic design to the ability to self-isolate.

This result confirms that design of the majority of housing is capable of ensuring each family member is able to practice self-isolation, if necessary. In addition, the locality of neighborhood commences from the design of these units, followed by that of the neighborhood and urban area, in order to provide the ability to fulfil the residents' requirements and offer sufficient services to prevent the need to go outside the local area.

#### 4. Discussion

This study has recognized the importance of urban design, along with services within each neighborhood, to fulfil human needs and minimize the need for transportation outside each area. While this has previously been studied in relation to minimizing CO<sub>2</sub> emissions, the advent of the COVID-19 pandemic has tested the ability of local services to facilitate quarantine and control transmission. Many studies have confirmed the extent to which privacy in terms of housing, and the role of the locality in neighborhoods, are essential targets for research. The basic underlying structure of vernacular settlements is influenced by factors such as the climatic conditions, local tradition, religion, economic foundation, and political stability [23]. Saleh et al. (2001) discussed the development of urban theory and planning from the viewpoint of traditional Saudi Arabian settlements [23]. The concept is directly influenced by local culture, climatic challenges, religion, tradition, and technology, which are all important for developing a successful planning theory [23]. The majority of house and neighborhood designs provide limitless access to space, resulting in issues with occupant privacy and a decline in socialization within communities [24]. Therefore, the discussion will be mainly around five main issues: (1) influence of Covid-19 pandemic worldwide; (2) locality in relation to human needs and the spread of COVID-19; (3) locality for remote villages in pandemics; (4) housing design and social distancing; and (5) application of Geographic Information Systems (GIS) for monitoring and managing the spread of COVID-19.

- Influence of Covid-19 pandemic worldwide

Pandemics have affected cities throughout history, and various health crises have had an impact on urban design and architecture. The Covid-19 pandemic, possibly the deadliest to affect public health in more than a century, highlighted a number of difficulties for towns [8]. A reconsideration of the customary city-design techniques may be necessary

in light of the surge in Covid-19 infections and mortality [8]. There is already acknowledgement of how novel actions and way of life modifications will affect the function and significance of balconies in Egypt. To comprehend how pandemics affect the built environment and the function of balconies throughout history and during the current pandemic, a literature review was performed [9]. The challenges of surviving in a post-Covid-19 urban century were consolidated by the role of architectural practice and teaching when responding, shaping, and rebuilding a new normal. These were avoided. Former US President Barack Obama delivered an unheeded warning in 2014 about the dangers of handling wild animals and food in urban settings. Johannesburg, the capital of South Africa, became the first major city without water in 2018 due to drought. In the capital cities of the three economic success stories of their region—France in Europe, Hong Kong in Asia, and Chile in South America—in 2019, forest fires raged and social crises were signaled [10].

- Locality in relation to human needs and the spread of COVID-19

This study has determined that it is vital for districts, villages, and neighborhoods to have adequate local infrastructure. At a micro level, neighborhoods should be able to provide all essential human needs, in order to manage and control the mobility of the population [25]. These include important services, such as schools, open spaces, markets, and health facilities [26–28]. In addition, the onset of the COVID-19 global pandemic has highlighted the importance of locality to support quarantine and self-isolation. Thus, the provision of the full range of services can enable the health sector to identify instances of infection, and such areas to be quarantined, with those infected supported in safely self-isolating within their homes [29,30]. This can allow easy tracking of the virus and ensure it does not spread outside the neighborhood.

This study has recognized the need to lockdown both countries and cities to prevent the spread of the virus [31] and has also highlighted the importance for local municipalities to be able to safely lockdown neighborhoods with positive cases. Health services and daily testing have been vital during the pandemic, including ensuring an effective use of self-isolation. However, it is also important to facilitate social distancing by both local services and open spaces, dependent on population local density and the presence of local facilities [32,33]. Local urban design can therefore be directed to minimize population density in order to achieve safe levels of social distancing and so address the challenges presented by the current pandemic.

The study identified a number of criteria to determine the appropriate space for local services, including open spaces, based on population density [34,35]. Hence, it is important that future areas are set aside to provide open spaces, and that local services consider the level of population density and how local citizens can safely practice social distancing. In addition, it is important to ensure each neighborhood has facilities for walking and sports, shopping, and schools, in order to minimize the need for transportation to other areas and thus the danger of spreading the virus. Open space is a vital provision in neighborhoods, due to its role in promoting social activities. Each district in Saudi Arabia has a public open space and each neighborhood has a privately allocated area available for local activities in open spaces. These open spaces are essential, and during self-isolation and local quarantining of specific neighborhoods with a high number of positive cases, negative locals can enjoy accessing open spaces during the quarantine period, which lasts about 14 days. Meanwhile positive individuals can self-isolate in their homes to control the spread of Covid-19.

- Locality for remote villages in pandemics

Remote villages are distributed across Saudi Arabia, and have been replanned and developed considering local facilities, services and infrastructure. During the Covid-19 pandemic, these villages were well managed due to their distance from the main cities, as they had efficient local facilities and infrastructure. In terms of self-isolation, these villages are well-managed and practice quarantine in contexts where all services are available. The survey encompasses many responses from remote villages, and the results can therefore reflect

how replanned and developed villages can best meet the need for public spaces and local facilities. A remote village can consist of a district or neighborhood, in which the locality and availability of services are essential to ensure such locations can be independent [36] and so able to practice isolation and prevent the spread of viruses such as COVID-19. Saudi Arabia consists of thirteen regions, each of which has its local municipality, towns, and remote villages. During the early stages of the pandemic, COVID-19 generally reached remote villages due to a lack of awareness, as well as social and cultural activities.

This was largely as a result of some remote villages being interdependent with their nearest neighbor, both socially and for administrative purposes, in particular the provision of schools, shops, and work. This indicates that locality should be allocated to each remote village, to minimize the need to travel, as well as healthcare planning and ensuring the ability of villages to self-isolate once cases of the virus are detected. This approach has already been applied in a number of countries to manage and control the spread of coronaviruses [37,38].

- Housing design and social distancing

Housing design plays a significant role in the ability of individuals to self-isolate, based on area, number of elements, and occupants. The residential sector needs over 2.32 million new housing units annually, but has yet to entertain environmental performance in its list of priorities [39]. Contractors find different ways to deliver higher levels of customization in residential units. However, in order to create a variety of options at an acceptable cost, it is essential to know the specific priorities of potential customers in terms of the type of roof, kitchen, toilets, etc. [40]. In some countries, detached houses are the dominant dwelling, with the average floor-area increasing in relation to those in countries with more one floor dwellings (i.e., flats), such as the UK, USA, Canada, Australia, and New Zealand [41].

The division plans for Saudi housing and the privacy of the “rooms” in each dwelling will contribute to the self-isolation of positive cases. It is important to note that there is currently no plan to increase these areas, due the commensurate need for increased energy to operate cooling and heating systems, which increases CO<sub>2</sub> emissions and fails to address the demand for environmental sustainability. This is particularly relevant as energy consumption in Saudi Arabia has increased at a rate of 7% annually, as a result of economic and population growth [42,43]. Housing design therefore needs to consider the area of residential unit per capita for all facilities within the dwelling, including dining room, living room, bedroom, kitchen, and other facilities. Housing design regulations in Saudi Arabia take into account both the occupants’ and their neighbors’ privacy. A typical site area in subdivision plans is about 625 m<sup>2</sup>. The built area of a site area is up to 60% of the area, with two floors and a possible additional third floor containing some service rooms. This gives the designer flexibility to design homes for the occupants and provide separate rooms and facilities. These separate rooms helped with self-isolation during the Covid-19 pandemic due to the involvement of many room elements and services.

In addition, it should be recognized that the needs of occupants tend to vary, depending on country and local culture, as well as the number of occupants. Hence, the ability to meeting social distance requirements in order to avoid potential coronavirus transmission is dependent on the design of each housing unit in terms of areas and number of elements. The subdivision plans in Saudi Arabia were approved by the “Ministry of Municipal, Rural Affairs and Housing”. Each subdivision plan will have local urban facilities, such as schools, public spaces, health centers, mosques, and market places. This will contribute by providing local privacy for each neighborhood, facilitating management of local 14 day quarantine periods for neighborhoods that have positive cases of Covid-19, so that local people can benefit from the facilities available and have their human needs for services met during limited self-isolation periods. As typical houses in Saudi Arabia are characterized by being spacious and containing a number of elements, they can be considered suitable to meet the requirements of social distancing and self-isolation.

- Application of Geographic Information Systems (GIS) for monitoring and managing the spread of COVID-19

One of the current global trends is that of urban development and urbanization, with the prediction that, by 2050, around 68% of the population will reside in developed areas [44]. Due to this rapid urbanization and development of technologies, facilities have currently become more diversified and complex [45,46]. Furthermore, urban developments have taken place on an unprecedented scale worldwide, requiring researchers and specialists to draw up smart management in urban and regional planning for smart cities, to handle the dramatic increase in demand for services and facilities [47,48], as well as disaster management [49].

Software application, such as geomatics and geographic information systems, can support the management of urban disasters, and should be employed in smart cities, creating a digital map of the physical world that can transform into a virtual environment as a referencing framework [49,50]. Furthermore, global online digital mapping, using GIS dashboards and applications, has been employed during 2019 and 2020 to track the spread of the coronavirus epidemic [51]. This was assisted by facilities managers being generally qualified to work within a top-down strategic level and link to a bottom-up operational level within an organization [52,53].

However, this kind of methodology for managing services and facilities is generally lacking on a city scale [54], so emphasizing the importance of putting such systems in place, particularly as geographical information can contribute to managing urban systems and facilities, as well as implementing further development [55,56]. In addition, locality and availability of essential facilities can be managed and monitored by many methodologies using GIS to highlight services and public spaces, as well as schools, health centers, shops, and mosques. This is a feasible approach, as location allocation digital mapping is among the most widely used methods in geographic information systems analysis [57].

- Public mobility system and its impact in Covid-19 dispersal

Public transportation is one issue that can contribute to Covid-19 dispersal. The government has issued some regulations to control the spread of Covid-19 on public transport. Firstly, education during the pandemic was online to avoid any risks that may arise due to people from different neighborhoods meeting. Secondly, work and official meeting have moved online for the same reason, based on ministry of health recommendations during the pandemic. Thirdly, each public citizen has a private account called “Tawakkalna”, which reflects their current health condition. All public and private people will require approval of their health condition through “Tawakkalna”.

## 5. Conclusions

The study investigated the current readiness of Saudi housing to accommodate curfew and self-quarantine as well as the readiness of Saudi neighborhoods for the implementation of partial curfew and self-quarantine, particularly in relation to local services and facilities. It has been found that the regulations for the approval of housing and neighborhoods can contribute to addressing pandemics, and these regulations can be developed to improve privacy and achieve smart cities. These findings can support future researchers in focusing on research in the areas of environmental concerns and the purposes of smart cities. It has been found that the onset of the COVID-19 pandemic has tested issues of locality and housing design in relation to the need to quarantine, both on a micro and macro scale. The study established the level of locality of neighborhoods in Saudi Arabia, along with the suitability of housing design, particularly the need to provide for self-isolation. The researchers undertook a survey of Saudi neighborhoods and housing, to determine how neighborhoods can remain self-sufficient and therefore isolate when required, in particular by providing services and urban facilities capable of removing the need for inhabitants to travel outside their neighborhood.

The survey covered families in many cities and towns across Saudi Arabia, with the results showing the majority of neighborhoods in Saudi Arabia to be well structured, offering sufficient public open spaces and vital facilities, and so capable of being self-reliant communities during a pandemic. Furthermore, the study confirmed that the typical housing

design in Saudi Arabia is spacious and can meet the requirements of social distancing, including the provision of sufficient elements to enable individual members of a household to self-isolate. Finally, the study considered the use of GIS to monitor and evaluate facilities and stem the spread of infection. The study concludes with the following recommendations:

- The design of housing units should consider the need for sufficient rooms to enable self-isolation, based on the number of occupants.
- The design of future neighborhoods should include all of the main facilities required to ensure a locality is self-sufficient, in order to minimize any unnecessary need for inhabitants to travel outside the area, particularly in the event of COVID-19 infections.
- GIS should be employed to analyze the capacity of each facility within all neighborhoods, in both urban and rural areas.
- Isolated areas should be managed by employing GIS to monitor the spread of COVID-19 across neighborhoods.
- The infrastructure of remote villages should be supported to avoid urban sprawl to cities and immigrants from villages, so as to alleviate issues of population density in relation to social distancing.
- Raise public awareness of the importance of practicing the safety procedures and ensuring the ability for individuals to social distance in all public facilities.

## 6. Future Work

Saudi Arabia has different climatic conditions, where the southwestern regions have mountains and wildlife habitat. The authors will conduct research to establish urban strategies specific to developing these regions, taking into account their natural resources, the forests, and the ecosystem, examining balance and protection.

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