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Health-Resilient Apartment Design for Post-Pandemic Housing: An Integrated Framework for Infection Control and Psychological Well-being

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ABSTRACT

The COVID-19 pandemic exposed critical failures in multi-unit apartment designs with respect to airborne and contact-based disease transmission. This study develops an integrated architectural framework for health-resilient housing using a triangulated mixed-methods approach. Data were synthesized from semi-structured interviews with virology specialists, sustainable engineering experts, and apartment inhabitants. The resulting validated model introduces several novel interventions: a transitional 'entrance garden' to serve as a biological buffer, a negative-pressure isolation room (AIIR) with dedicated facilities, and a 'safe path' escape staircase for secure medical access. Technical enhancements, including air-lock (SAS) doors, wind curtains, and self-cleaning materials, are integrated to minimize viral loads in high-traffic areas. After a three-phase validation by architects and medical experts, the study concludes with a procedural guide for local authorities to standardize health-resilient infrastructure in future residential developments.

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1. Introduction

The results of pandemic reviews indicate that the architectural design of most current residential apartment buildings is not well-suited to confronting pandemics, owing to the absence of standards that address residents' emerging infection-related needs [1]. Those needs are health (physical and mental), individual (comfort and privacy), vocational, educational, social, recreational, or sports during the period of staying at home. Adding a vital need: to give the building immunity against sick building syndrome and to provide internal protection for residents, in light of growing evidence that airborne transmission via fine aerosols is a primary driver of infection in poorly ventilated indoor environments [2, 3].

One of the most essential lessons humanity has learned from the COVID-19 experience, as with other seasonal influenza pandemics, is that, in the face of pandemic spread, countermeasures must be one step ahead of pandemic solutions to enable resistance to infection. The previous experience calls for a reconsideration of lifestyle changes related to the architectural design of residential apartments from a health perspective [4]. Isolation, social distancing, and quarantine are practical solutions that should be adopted in homes and cities [5]. Scientists and researchers began to ask how to cope with and adapt to the new situation, how architects and planners could confront these threats, and how to balance quarantine spaces with essential human activities [6].

People's fear for their families may be a primary factor in choosing to design healthy homes from the inside, as havens from disease. When diseases spread, governments used home quarantine to combat infections. Even homes can pose a threat if an infected person cannot be far from the family. The residences and apartments, which appeared to be the most critical settings for human awareness of infectious diseases, required preparation for this situation.

The proposed model in this research provides interventions and recommendations for designing a healthy apartment that is less susceptible to airborne or contact-borne infections. The interventions also consider the psychological health of those forced to remain in the apartment (part of a multi-apartment building) due to a contagious respiratory disease [7].

Interventions include a proposal for an entrance garden, for which user interviews confirmed that it could be an exceptional solution for creating a healthy transitional space (between inside and outside) during the period of home confinement. The containment area at the apartment entrance includes boundaries to prevent the transfer of external viruses/diseases to the interior spaces, with a washing and initial storage station and a differential level that serves as a mechanism for disposing of shoes before entering the safe part of the apartment. In addition, the design of a negative-pressure isolation room system connected to an external green balcony allows communication between residents of the same apartment without the risk of virus transmission or infection.

Studies focused on these interventions began to appear as the pandemic spread, presenting them as tools for crisis management. This study discusses how to introduce mechanisms in residential apartments to make them a tool to be considered in all circumstances, based on the Corona experience, where the provided solutions are not for temporary use to solve a crisis, but rather to be one of the standards that the designer follows when designing a multi-story residential building.

Tokazhanov *et al*. clarified that overcrowded housing, which impedes social distancing, worsens comfort during a stay-at-home order due to inadequate privacy [8]. This is evident in multi-apartment buildings, and the problem is more pronounced in some high-density cities than in others. As a result of dwindling land allocated for construction, sharp rises in land prices, high population density, and high construction costs, citizens have shifted toward multi-apartment housing, which is more expensive than in other cities. In the event of a pandemic spreading, the solutions proposed globally to increase the immunity of buildings against the aggravation and spread of infectious diseases and pandemics among the population by growing spaces will be unrealistic for a large segment of the population, especially since the prices of apartments are not proportionate and are not linked to the income levels in many countries. The study offers reflections on the context of design justice, given the limited literature on it as a design approach that serves marginalized communities and reduces inequality among the most disadvantaged groups in society [9]. Hence, integrating health-security features within affordable housing is a matter of design justice, ensuring that low-income populations are not disproportionately vulnerable to environmental pathogens during lockdowns [10].

The World Health Organization (WHO) defines a pandemic as the worldwide spread of a new infectious disease across multiple countries, affecting many people who have little or no immunity to the virus, or for whom there is no vaccine or medicine to prevent its spread [11]. The world has resorted to various non-pharmaceutical strategies to reduce the spread of the epidemic until a vaccine is obtained to reduce the number of deaths, such as hygiene and sterilization, isolating the patient, quarantine, social distancing, preventing gatherings, using masks, travel restrictions, closing schools, and work offices [12]. So, turning to distance education and remote work, this necessarily means spending more time in homes and apartments, which measures have been linked to an increasing incidence of depression and anxiety, and a decline in the physical, mental, and psychological state of a large number of the population, especially in high-rise buildings.

A survey of professionals was administered to assess the effects of the COVID-19 pandemic on building health. The pandemic had a significant impact on building health. Previous studies have called for integrating architectural, environmental, medical, psychological, and landscape design as a natural response to the pandemic experience. The lack of interdisciplinary integration and pandemic preparedness has indicated risks arising from home isolation [13], such as increased violence against women, weakened social care, and declining mental health, among others [14].

It is necessary to focus on the design, construction, and operation of buildings to ensure occupant health, prioritizing high indoor air quality and reducing the risk of infection. Design changes include adopting less-dense layouts, using hands-free systems, and installing antibacterial fabrics and coverings [15]. A previous study reported that, following the COVID-19 pandemic, the functional space must increase the number of vertical and horizontal movement circles and the width of horizontal corridors [16]. All future designs must be energy- and water-independent, self-sufficient, and powered by renewable energy sources. The goal is to be independent of the external world and to reduce risks in the event of a complete lockdown [17].

General indications were proposed for the design, such as avoiding sharp corners for difficulty in cleaning, using non-absorbent, healthy, sustainable, and easy-to-clean materials, using antibacterial finishing composite materials and self-sterilizing innovative materials such as bronze, copper, and brass, staying away from stainless steel, steel, cardboard and plastic materials as a virus lives on them for a period 2-3 days use germ-resistant floor surfaces, countertops and sanitary monitoring systems. Porcelain, tile, and linoleum are commonly used on kitchen, bathroom, and laundry room surfaces [5]. Using touch, intelligent sensing, voice response, and remote control technologies in design and construction [18]. In general, a group of studies believe that the design of healthy residential apartments should consider some critical issues for the post-pandemic phase: windows and views that support recovery; lighting levels linked to multiple uses and users; regulating the biological clock through comfortable bedrooms; living rooms that receive clean fresh air with a connection to the nature; enhancing the role of balconies, and emphasizing physical distancing as a guideline; and reducing the occupancy rate which is essential in determining unit sizes and layouts [19].

To make a difference in housing reform, architects have begun to follow a trend toward simpler forms, using fewer curves, employing modern materials with a sense of function, and moving away from decoration because of its cost and its role in dust accumulation. Architects are designing therapeutic environments that extend beyond aesthetic considerations, purging disease and pollution; these features embody modern preoccupations, including the therapeutic effects of daylight, fresh air, and a view of the outdoors. Those buildings feature larger windows, balconies or terraces, flat roofs without dust accumulation, and white paint that emphasizes a clean appearance [5]. Currently, the global health strategies should include the built environment at higher levels to prevent the spread of infections. Multiple studies are needed to address COVID-19 [20].

A series of studies published after the announcement of the COVID-19 pandemic included insights and analyses from researchers and architects who developed practical recommendations to update home design requirements for the post-COVID period. Perceptions included changes in home space, preparations for residential space, and home design supplements [1]. The goal is to develop designs that account for both physical and mental health to prevent the transmission of infection and protect physical and psychological health. At the same time, suggested interventions for post-COVID home design did not address apartments and multi-unit buildings. Independently, appropriate design strategies for infection control could be adopted, such as designs that promote social distancing; designs that enhance natural ventilation, daylight, or sunlight; designs that use adaptive finishing materials and construction methods; and flexible designs that emphasize sustainability [21]. Some studies have also shown that solutions can be used to purify indoor air of airborne pathogens, such as hypochlorous acid (HOCl) [22].

There is no doubt that a home with a garden and outdoor courtyards makes the home quarantine period a better experience in all its dimensions. Still, the problem is more difficult for apartment users. The architectural designs of residential buildings must keep pace with developments in telehealth and remote care. Because the service can be provided remotely, at least one room in the apartment must meet the requirements for remote care, given that viruses continue to evolve.

Self-isolation of healthcare providers and patients, and the provision of healthcare remotely, help reduce the risk of disease transmission. Preventing direct physical contact, providing continuous care for users, and reducing infections, thereby reducing deaths during viral outbreaks [23]. Recent studies have shown that telemedicine has increased patients' access to healthcare, leading to greater patient satisfaction [24]. To ensure sustainable integration between the healthcare and residential sectors, the necessary telemedicine infrastructure must be provided, particularly in apartments where this service will be delivered.

Telehealth uses live videoconferencing and phone calls with healthcare professionals to ask questions, gather necessary information, triage patients, consult supplies, and follow up. A person can self-monitor symptoms at home during recovery. Regular checks of vital signs, such as respiratory rate, blood pressure, and oxygen saturation, are required at home [25]. There is no doubt that there are some obstacles and challenges such as: technical supplies, ensuring the privacy of the examination, data security and method of reimbursement, clinical examination for diagnostic purposes, the level of some segments of society, training of healthcare providers and patients, the relationship between the doctor and the patient, acceptability, poor internet connection and lack of comprehensive access to technological structure [26].

1.1. Infection Transmission and the Built Environment

The built environment, including apartments, can serve as a vector for disease transmission by stimulating close interactions between individuals, through objects (e.g., materials that may carry infectious agents), and through viral exchange and airborne transmission. Studies suggest that indoor environmental quality (IEQ) is a critical determinant of viral load concentration and persistence in residential units [27]. The number of building occupants, building type, occupancy rate, and indoor activities facilitate the growth of human-associated microorganisms [28].

Studies show that patients and healthcare workers contaminate most touchable surfaces in MERC patient units, and that viable virus can be spread via respiratory secretions from clinically recovered patients. These studies emphasize the need for strict environmental hygiene practices for surfaces and for an adequate isolation period based on laboratory results, rather than solely on clinical symptoms [29]. The indoor environments of multi-apartment buildings are affected by outdoor particles differently than those in individual homes, because airflow is more complex in multi-apartment buildings. A simulation study of winter airflow showed that air infiltrates from the outside into the lower part of the building and leaks out from the upper part [30]. This showed that the lower floors of the multi-story building were exposed to higher concentrations of fine particles than the upper floors [31].

To understand the transport, dispersion, and evaporation of saliva particles generated by a human cough [32], a method of generating saliva droplets in the air is employed, mimicking a real cough at 20 °C and 50% RH. It has been found that virus-laden saliva droplets can be transmitted up to 6 meters when the wind speed is 4-15km/h. When wind speed is nearly zero, saliva droplets travel no more than 2 meters. As is known, the influenza "A" virus circulates continuously through aerosol or respiratory droplet transmission. The particles of the Saliva droplet disease carrier could not travel beyond 2 meters at an approximate wind speed of 0 m/s [33]. Infectious diseases are mainly transmitted through air, water, and surfaces. In this study, solutions for the two media, air and surfaces, are discussed and highlighted as design interventions for apartments.

1.2. Virology: A Reference for the Design Model

To develop an anti-infection design model, it is necessary to address pathogen behavior and their interactions with indoor air quality factors and other factors, as indoor environments contain various pollutants [33]. Airborne transmission occurs because fine microbial particles remain in the air for extended periods and are carried with the air a person inhales [34]. When infected people sneeze, cough, or exhale, relatively large respiratory droplets (>10 micrometers) carrying viruses are transmitted [33]. One cough/sneeze in a space can release about 40,000 droplets at speeds of 50-200 m/h, each containing millions of viral particles. Theoretical models of aerosol dispersion confirm that standard 2-meter distancing may be insufficient in enclosed residential corridors with stagnant air [35]. One study on the indoor environment and indoor air quality developed a conceptual model to improve indoor air quality while considering the risk-control hierarchy for virus transmission [28], thereby helping designers achieve sufficient ventilation while avoiding virus-related risks.

Studies confirmed that airflow patterns influence the microbial populations that grow indoors. The interactions between outdoor air and indoor spaces influence microbial diversity. Most importantly, heating, ventilation, and central air conditioning (HVAC) systems influence the size and diversity of microbial communities [28], and the best ventilation method remains opening a window.

The virology literature indicates that sunlight transmittance is inversely associated with influenza transmission, highlighting the potential for viral spread under certain environmental conditions [36]. A study by Schuit (2020) found that the degradation rate of SARS-CoV-2 in aerosols is significantly affected by sunlight transmittance, whereas RH alone does not. However, minor interactions between RH and other factors have been demonstrated [37].

Some studies show that far-UV light in the range of 207 to 222 nanometers can effectively eliminate airborne viruses at very low doses, such as 2 mJ/cm2 at 222 nm, inactivating more than 95% of aerosolized H1N1 virus. When the same test was performed on three-dimensional (3-D) models of human skin, it did not harm the skin or eyes [38]. Airborne viruses can be eliminated by irradiation with a 222-nm UVC excimer lamp within 60 seconds [39].

Studies focused on the psychological aspect, and the above studies showed the importance of plants and their role in improving mental health and well-being. The other element to be studied is the plant's technical application in an apartment. A study shows that connecting with nature is one way to thrive [40]. Accordingly, using plants may reduce the difficulty of spending time in a residential apartment; therefore, it is necessary to review relevant research on various green wall systems and select the most appropriate option for residential flats. However, it is essential to address differences between systems in installation and construction methods; the most suitable solution is to use LWS units, which differ in configuration, weight, and assembly [41]. To be effective, all engineering and scientific efforts should be governed by procedures that require a new standard design that reduces the risk of infectious disease transmission. It is included in the annexes to laws on construction, buildings, planning, city planning, building permits, civil defense approvals, and relevant authorities. To reduce the transmission of infection in multi-unit buildings, it is not enough to clean surfaces or encourage residents to adopt good behaviors. Usual practices must adapt to avoid gatherings [42].

While global studies have addressed infection control in healthcare facilities, there remains a critical gap in the architectural literature regarding the specific challenges posed by multi-unit apartment buildings. Despite the surge in research following the COVID-19 pandemic, a critical gap remains in architectural literature. While infection control has been extensively studied in healthcare facilities, there is a scarcity of frameworks specifically designed for multi-unit apartment buildings. Most existing residential recommendations have focused on temporary 'crisis management' or individual homes, leaving high-density urban residents vulnerable.

The novelty of this study lies in its transition from temporary 'crisis management' toward a permanent, integrated 'Immune System' for multi-unit residential architecture. Unlike existing literature that primarily focuses on healthcare facilities or individual homes, this research introduces a linked network of architectural interventions validated through a three-phase process involving virology and engineering experts.

Key original contributions include:

1. The Integrated AIIR-Skylight System: A negative-pressure isolation room (AIIR) that is not a standalone feature but is technically linked to a central 'negative' skylight, utilizing pressure differentials to expel contaminated air actively.
2. The 'Safe Path' Dual-Function Staircase: An original vertical circulation design that serves as a secure egress for infected residents and a dedicated, isolated entry for medical personnel, effectively breaking the chain of infection within a shared building core.
3. Transitional Sterilization Zones: The introduction of an entrance garden and foyer containment area designed as a biological buffer, incorporating differential floor levels and wind curtains to manage pathogens at the unit's threshold.

Finally, this study moves beyond theoretical design by presenting a Procedural Guide (Table **1**) intended to standardize these features as mandatory building permit requirements, ensuring 'Building Immunity' is accessible to marginalized communities in high-density urban settings.

2. Research Methods

This research has both qualitative and quantitative approaches, obtaining interviews and analysis (Fig. **1**). The rationale for adopting a triangulated mixed-methods approach is to bridge the critical gap between clinical health data and architectural spatial design. A single-method approach would be insufficient to address the multi-dimensional nature of pandemic resilience; therefore, qualitative semi-structured interviews were utilized to capture the complex lived experiences of inhabitants and the specialized medical requirements of virologists. These insights were then synthesized with quantitative Computational Fluid Dynamics (CFD) and daylight simulations to provide objective, technical validation of the proposed architectural interventions. This dual-pronged strategy ensures that the resulting model is not only socially and functionally grounded in user needs but is also scientifically effective in managing the biological behavior of pathogens in high-density residential environments. The primary research strategy is to propose design interventions for residential apartments that address users' health, indoor environment, psychological, and physical needs, thereby enhancing indoor quality and controlling the transmission of airborne and contact-based diseases, thereby facilitating home confinement.

The study focuses on residential apartments. Two questions are posed: How can mechanisms be used to improve the apartment building's immune performance, thereby reducing its infectious disease transmission and improving health?

The hypothesis considers four aspects: the health aspect, the physical aspect, the psychological aspect, and the environmental aspect to improve indoor air quality in apartments through functional design.

In the previous three stages, the interviews were analyzed using manual thematic analysis: the necessary codes, statements, and facts were identified; a complete functional framework for the proposed architectural distribution was formulated; and an imaginative prototype design was developed, including proposed solutions for operating an immune-resistant apartment. Confirmations were obtained on the virus's behavioral aspects and the proposed systems and materials through interviews with specialists in each field, including a supervisor, a mechanical engineer, a materials expert, and a virologist.

2.1. Data Collection

The use of a triangulated mixed-methods approach aligns with current architectural research frameworks that aim to bridge the gap between clinical health data and spatial design [43]. Semi-structured interviews were conducted with inhabitants of the selected apartments, sustainable engineering experts, and specialists in preventive medicine and virology from Palestine, the study area. Interviews were analyzed in light of prior studies, yielding indications for design interventions within the residential apartment. Interviews focused on the user's experience during COVID-19 quarantine, the expert's visions for healthier environments, and the engineering expert's proposals.

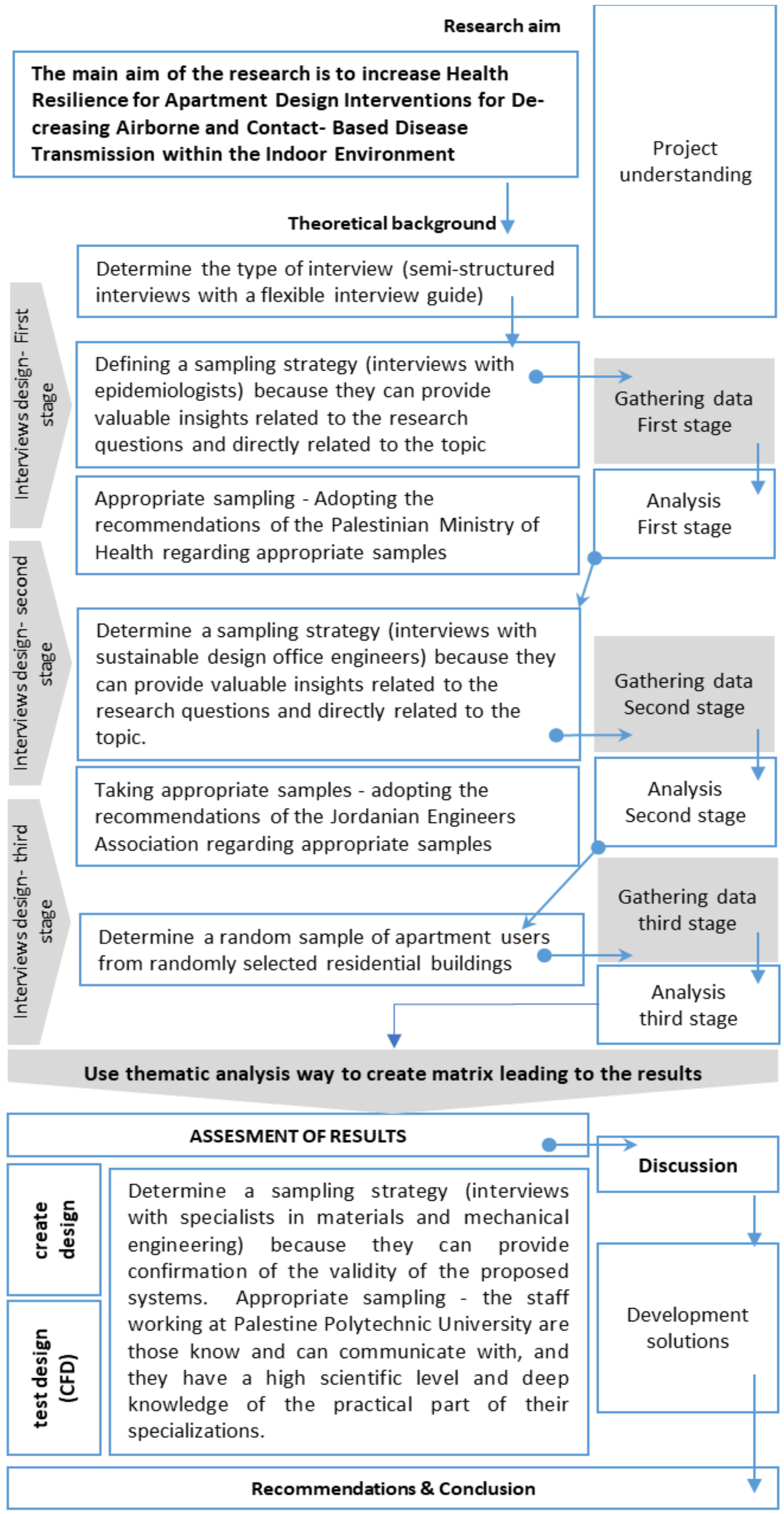

Figure 1: The sequence of the research approach. This diagram illustrates the triangulated mixed-methods research design, synthesized from qualitative interviews. It outlines the transition from data collection to the three-phase validation process (Functional, Architectural, and Virological) for developing the final residential model.

To ensure the validity of the design interventions, a triangulation strategy was employed, synthesizing data from three distinct stakeholders until 'data saturation' was achieved among the 34 inhabitants. Furthermore, the model underwent a rigorous three-phase validation process: initial framework discussion, examination by consultant architects, and final review by virology experts to ensure the behavioral aspects of pathogens were addressed.

To ensure the reliability of the qualitative data, a structured approach was employed in which participants' viewpoints were compared to identify consistencies and outliers. Data saturation served as a primary reliability metric; for the inhabitant group, interviews continued until the 34th participant, at which point responses became repetitive, and no new themes emerged. Additionally, high response rates among the specialist groups—87% for virologists and 82% for engineering experts—further reinforced the reliability and representativeness of the expert data.

2.2. Target Groups Selection Criteria

Interviewees were selected in an organized manner, relying on consulting the relevant departments and ministries to obtain their guidance regarding obtaining the names of the people closest to the experience and whose insights could be valuable to the research, in addition to their contribution to understanding the needs, preferences, challenges, and expectations related to the problem to reach the desired objectives. To ensure high credibility and depth of insight, participants were selected based on specific professional benchmarks and frontline experience:

- **Group 1:** Virology and Preventive Medicine Specialists (n=13): This group comprised heads of preventive medicine departments within the directorates of Hebron Governorate, covering the northern, central, and southern regions. The Palestinian Ministry of Health specifically recommended these participants due to their direct clinical experience in combating the COVID-19 pandemic and seasonal influenza. Their background provided the study with critical data on pathogen behavior and medical requirements for isolation environments.
- **Group 2:** Sustainable Architecture and Engineering Specialists (n=9): Participants were senior specialists from local engineering firms specializing in environmental and healthy building design. Selection was based on professional registries from the Jordanian Engineers Association (Al-Quds Center) and the Palestinian Higher Council for Green Building, the primary authority for sustainable construction in the region. Their expertise ensured that the proposed interventions were technically feasible and aligned with green building standards.
- **Group 3:** Residential Inhabitants (n=34): This group consisted of parents residing in multi-unit apartments within the Hebron Governorate. Participants were selected to represent the primary demographic affected by home confinement, providing essential data on the lived experience, psychological pressures, and functional deficiencies of existing high-density housing during the pandemic.

The inclusion of these high-level professionals—evidenced by response rates of 87% and 82% from the medical and engineering groups, respectively—ensures that the study's framework is grounded in authoritative regional expertise and verified clinical needs.

The sample sizes and selection criteria for this study were designed to balance technical depth and representative user experience while mitigating potential biases.

The selection of expert participants (13 virologists and 9 engineering specialists) was governed by the niche nature of these disciplines within the study area; however, the high response rates of 87% and 82%, respectively, ensure that the findings represent a significant majority of available regional expertise. For the inhabitant group (n=34), the sample size was determined by data saturation, reaching the point where responses became repetitive and no new design needs were identified.

The focus on Hebron Governorate provides a highly representative sample of the Palestinian residential context. Hebron has the country's highest concentration of multi-unit apartments (approximately 62,950 units) and features a temperate, mountainous climate characteristic of major urban centers such as Jerusalem and Ramallah. This ensures that the design interventions apply to the region's primary residential typologies and climatic conditions.

Participants were identified through multi-institutional referrals, including the Ministry of Health and the Palestinian Higher Council for Green Building. Furthermore, the study utilized a triangulated mixed-methods approach, cross-referencing qualitative interview data from three distinct stakeholders against objective quantitative CFD and daylight simulations. This triangulation ensures that the final model is not biased toward a single perspective but is a synthesis of clinical, technical, and lived experiences."

2.3. Interventions Extraction Process

The interview answers were grouped into the following themes: Universal design and accessibility; space planning and layout; indoor air quality and ventilation; material selection and surfaces; health and safety considerations; lighting and natural elements; and acoustics and noise control. A set of interventions was proposed based on the interviewees' proposals for solving each problem, informed by their experiences and visions.

A structured approach was followed to ensure accuracy, reliability, and validity. Meaningful units of interview information were manually coded, and the codes were grouped into broader themes. This phase involves grouping related codes to identify common patterns, themes, or concepts. Answers to connections, relationships, and patterns within and across categories were outlined. The viewpoints of different participants were compared, and similarities and differences were noted.

The thematic analysis followed a rigorous manual coding process. Initially, transcripts were reviewed to identify 'meaningful units' of information—specific statements or facts related to pandemic experiences and architectural needs. These units were then assigned initial codes and systematically organized into broader themes, such as 'Indoor Air Quality' and 'Space Planning'. To explore the relationships between these themes and the stakeholders, a matrix analysis was utilized. One axis represented the interview questions, while the other categorized responses from the three target groups (virologists, engineers, and inhabitants), enabling the identification of recurring patterns and priority design interventions.

2.4. Building and Testing of the Model

The proposed design intervention model was developed based on interviews conducted in the previous study and virological indications. The following points describe the generated model:

1. The model location is in Hebron Governorate, specifically in Dura city (the southern part of Hebron), where the interviews determined its requirements. Firstly, the interviews were approved by the Palestinian Ministry of Health. Secondly, based on the first determinant, interviews were conducted with users in the same geographical context to ensure consistency in the samples and their conditions during data collection. Thirdly, Hebron city climate represents a large area in the West Bank (the mountainous zone, which has a temperate climate, including Bethlehem, Jerusalem, Ramallah, Nablus, and other cities), where the largest number of apartments across the governorates of Palestine is concentrated in Hebron Governorate, as the number of flats reached about 62,950.
2. To substantiate the spatial configuration of the 'Housing A' typology, this study utilizes a typical floor plan mirrored across a central vertical axis, a design most in demand in the Hebron Governorate (Fig. **2**). This layout consists of two identical apartments per floor, each designed to accommodate a standard family of six.
3. The number of floors and building specifications were determined based on the organizational use of “Housing A” type (7 floors as maximum), taking the standard family size (6 persons).
4. The proposed design adopts passive design strategies, such as glazing ratio, wall pattern, and insulation.
5. Simulations such as computational fluid dynamics (CFD) and daylight simulations were made using the DesignBuilder software.

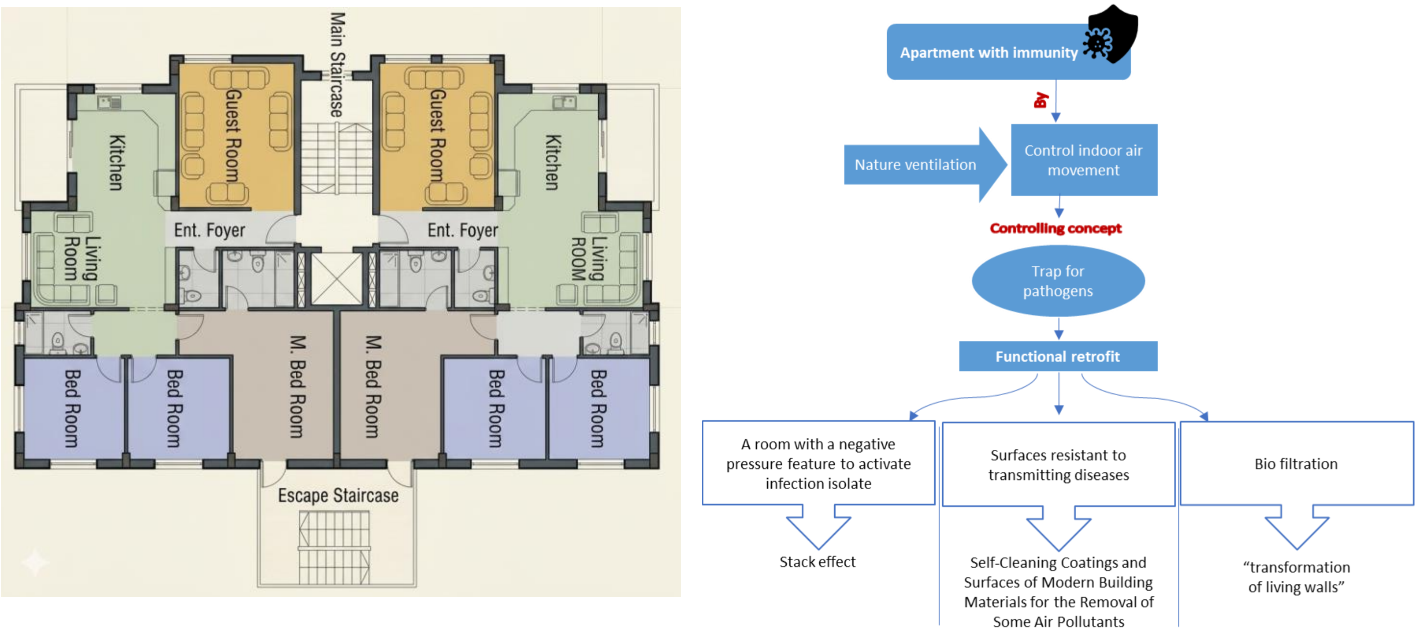

Figure 2: A prevalent apartment building plan in Hebron Governorate (Source: Local Engineering Offices-Masri) (Left), and the proposed model approach (Right).

Testing this model is a necessary step to generalize its results and make them available to designers and decision-makers in public health and architecture to achieve healthier apartments. Therefore, it was tested in successive phases: the first phase was the functional framework phase, during which the initial design guidelines were discussed with experts in the field. The second phase involves presenting, examining, and modifying the model developed by a selected group of consultant architects. These architects were chosen because they are qualified to design sustainable buildings. The modification session includes the researcher's information, research needs, and objectives. The third phase involved testing the model with virology experts, who discussed the virus's behavioral aspects and the responses of the proposed systems and materials (Fig. **3**).

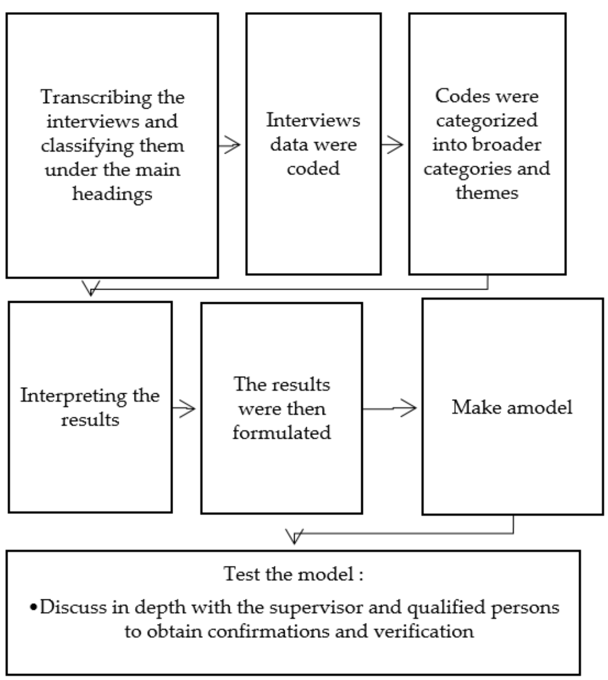

Figure 3: Data analysis process.

These phases enabled the researcher to transfer the discussion into a drawing to highlight the different interventions. The proposed model has sufficient flexibility to account for the specialist's directions, including the

effects of the negative-pressure system, the design's accuracy, the dimensions, and potential system defects, thereby enabling a deeper understanding of the details and clarification of specific points. The model was developed based on the standard apartment design in the Hebron governorate. The results are presented in a table of design recommendations for designers seeking to design a residential apartment resistant to infectious diseases. The Ministry of Health can use it as a procedural guide to grant the necessary approvals for multi-unit residential licensing. buildings with shared facilities.

The study employed a triangulation strategy to validate findings, synthesizing qualitative insights from three distinct stakeholder groups with quantitative data from CFD and daylight simulations. Furthermore, the resulting model underwent a three-phase formal validation process:

- Phase 1 (Functional Framework): Initial design guidelines were debated with field experts to establish the core logic.
- Phase 2 (Architectural Examination): A group of qualified consultant architects reviewed and modified the model to ensure technical feasibility and sustainability.
- Phase 3 (Virological Efficacy): Virology specialists conducted a final review, specifically testing the model's architectural responses (such as the negative-pressure systems and material selections) against known pathogen behaviors.

3. Results and Discussion

Semi-structured interviews were analyzed to identify optimal design interventions for a healthy apartment that are consistent with the design requirements of standard residential flats. The resulting data was summarized into matrix sheets. Subsequently, common themes were identified and confirmed among virologists, sustainable design specialists, and apartment residents. They highlighted recurring ideas and standard methods to inform the development of solutions based on their experience.

After extracting themes and coding them, the interview results are presented in a matrix with two axes: the first axis represents the interview questions, and the second axis represents the interviewees' responses, divided into three categories. The interviewee's responses were then analyzed in relation to the themes raised in the interview to identify the features, components, and specifications of the ideal apartment model that ensures immunity and fulfills the intentions and aspirations of inhabitants, medical staff, and experts. The networking relationships among the design components, including rooms, facilities, and architectural design, were explored.

Based on the results matrix, we can introduce the amendment priorities into the functional framework for apartment design. This is based on converting the preferences, desires, fears, and suggestions of the research categories into numerical values and ranking them by priority to yield a higher aggregate score. Independently, a set of essential results can be highlighted here:

1- Some of the interviewees discussed issues related to the necessity of providing isolation space inside the apartment alongside the accompanying needs of a bathroom and an external exit linked to the safe path (danger exit), focusing on a strong relationship with the outside nature to protect the isolated person from the confinement pressures.

2- The experts and specialists discussed the priority of providing access to sunlight for all the components of the apartment, and making a periodic and successive sterilization and cleaning of the spaces.

3- The inhabitants expressed their intention to go outside the apartment during periods of confinement, thereby enhancing exposure to fresh air and increasing airflow inside. This, in turn, improves their psychological conditions. Therefore, it was necessary to devise a solution that simulates the inhabitants' subconscious and creates their own space, but outside the apartment's entrance. It can be a proposed balcony serving as a transitional space between the staircase and the apartment, as shown in the model presented in the following sections.

4- Specialists and experts ensured that infection can be controlled through surfaces and materials by providing access to outdoor views and daylight, at the building level and, in particular, at the apartment level. They mentioned that the proposal can include a sequence of privacy, cleaning, and sterilization phases to be followed for all items entering from outside.

5- The residents, specialists, and experts emphasized the need for health security within the apartment for people of all ages, particularly older adults and children.

6- Details regarding materials and surfaces are provided, and the importance of reducing the number of people infected through direct contact with contaminated surfaces is emphasized, as recommended by specialists. Field tests have demonstrated that copper-based alloys significantly reduce the half-life of respiratory viruses on high-touch surfaces compared to stainless steel or plastic [44].

7- The answers of the interviewees show that the global trend calls for developing the building design to be flexible for different conditions, which can accommodate areas of remote treatment, remote work, and remote study. The current apartment's layout indicates the difficulty of quarantining certain groups of society, except when health requirements are taken into account.

8- Acoustics and sound insulation received the fewest votes from the interviewees. Still, their role cannot be overstated, as some users reported feeling anxious upon hearing others coughing and sneezing outside the apartment, which may contribute to increased psychological distress.

9- Other results show that turning residential apartments into healthy ones needs more expenses, more interest, and more flexibility to include the existing built apartments.

Major interventions, such as negative-pressure rooms, material and surface identification, and the establishment of a green zone, can be implemented to improve the apartment's indoor air quality. The model was treated as a specific case with respect to orientation and as a general case with respect to the apartment's organization, functions, and reconfiguration. Some lessons were learned from the COVID-19 quarantine period, which confirm that the architectural scientific community should rethink its approach to residential design. There is no doubt that planning will take a new direction, moving away from the city rather than into it, as a result of the shift to distance learning and remote work policies, following the upcoming change in people's livelihoods. Vertical building orientation will inevitably become futile over the long term, while health problems must be addressed at the individual level, given the built environment resulting from the quarantine period.

Different design interventions can be identified depending on the interview results, as they are included and highlighted in the proposed model. Focusing on the internal design mechanisms, there is a necessity of thinking about the immunity of buildings by: 1) Reshaping the spaces of isolation and sterilization and disinfection tools; 2) Maximizing the use of daylight and ventilation to reduce transmission of infection; 3) Developing mechanisms to limit the spread of infection; 4) Connecting building interiors with nature by including the garden in designs; 5) Increasing technological development for remote communication with families, businesses; 6) Enhancing the privacy in the design to reduce gathering people, which in turns reduce infection. The guest room is often empty in Palestinian society, making it readily available for e-learning or quarantine. The emergence, increased use, and growing popularity of telehealth and telemedicine among health and medical care providers and recipients of health services will affect the built environment in which these services are delivered and received. From a biological point of view, immunity is the state of being insusceptible or resistant to a noxious agent or process, especially a pathogen or infectious disease. Immunity can occur naturally or be induced by immunization [45].

One of the most critical design considerations is flexibility, which increases available space and enables adaptation to changing needs at each stage. It became clear that designing apartments after or during the pandemic requires functional modifications to improve indoor air quality. This ensures that apartments are sufficiently flexible to support home isolation during periods of confinement.

The interventions were presented in terms of space, intervention form, and architectural design response. The most important intervention is the entry to the apartment through a garden, which reduces the risk of infection transmission from the outside. Access to private or semi-private green spaces has been positively correlated with reduced cortisol levels and improved psychological resilience during periods of home confinement [46]. These healing landscapes serve as a vital buffer against the stresses of isolation [47]. The garden with direct connection to the containment space has two directions for circulation: The first direction leads to the isolation room in case of injury as a visual connection, which, in the normal situation, is a guest room, a room with flexible furniture that is easy to transform; The second direction leads to the living room and kitchen. The spatial organization is illustrated by a functional connection diagram that maps the relationship between the central shared lobby and the private residential zones (Fig. **4**).

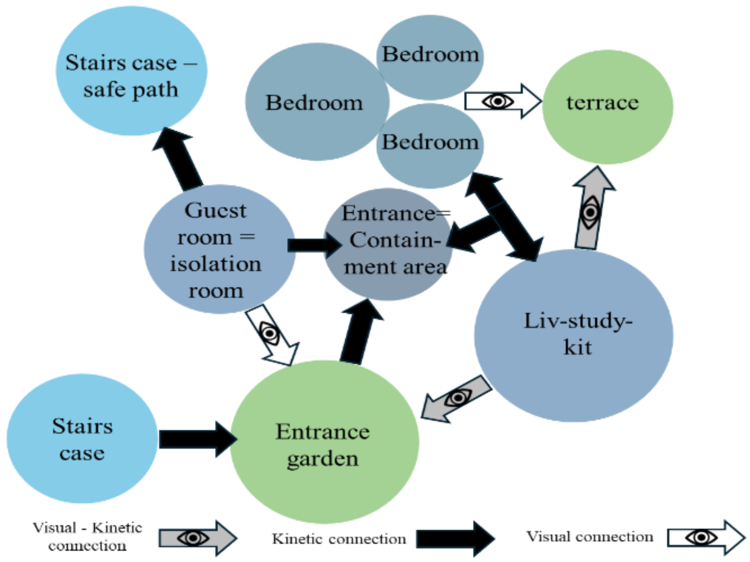

Figure 4: Apartment spaces connection diagram. This functional diagram maps the "Safe Path" concept, illustrating the spatial link between the negative-pressure isolation room (AIIR) and the escape staircase. It highlights the sterilized foyer as the central node that isolates contaminated paths from the primary residential living areas, effectively breaking the chain of infection.

The residential floors are identical, with minor variations. One design feature is that the living space, kitchen, and dining area can be oriented in four directions and connect to two gardens, one for summer and one for winter (Fig. **4**).

The research findings regarding the entrance garden as a transitional sterilization zone align with recent studies emphasizing that indoor environmental quality (IEQ) is a critical determinant of viral load persistence. However, while prior literature largely focuses on internal air filtration, this study proposes a spatial intervention at the building's threshold. This moves beyond the 'crisis management' tools identified by Hanna and Budds, suggesting that the entrance garden functions similarly to the 'healing landscapes' found in clinical settings, which have been positively correlated with reduced cortisol levels and improved psychological resilience.

The staircase opening at the building's height is continuous, and a windcatcher has been installed to admit fresh air and increase ventilation on hot summer days. These openings are equipped with a valve that can be opened and closed as needed (Fig. **6**).

As shown in Fig. (**5**), the proposed model accounts for common apartment requirements in the Hebron region while highlighting key findings from the interviews. To clarify, the main staircase is at the bottom of the diagram, and the escape staircase is at the top. The safe path is to connect the isolation room (guest room with its own W.C.) to the entrance via the sterilized foyer.

The morning activities are linked to another balcony (the eastern and western parts of the model building) that adjusts the bedrooms, as a visual connection to the outdoors via verandas or large glazing areas is a key architectural determinant of resident well-being during quarantine [48].

Figure 5: The proposed mirrored model is based on the common apartment plan. The figure provides a detailed architectural layout that integrates the entrance garden with internal corridors, designed to facilitate cross-ventilation and promote psychological well-being during confinement. These drawings provide the necessary spatial evidence for the dual vertical circulation system—comprising a main staircase and a dedicated 'Safe Path' escape staircase—which is a core requirement for health-resilience.

The floor must have separate levels to maintain cleanliness. A negative-pressure room (duct) is included alongside the isolation room to enhance ventilation during the pandemic.

The foyer/lobby of the multi-residential building is proposed to receive a functional treatment: installing wind curtains at the entrances to prevent pathogens and other dust from entering the interior and to provide storage for online and delivery purchases. Studies on aerodynamic barriers confirm that properly calibrated air curtains can mitigate up to 80% of airborne contaminant transfer between high-traffic entryways and building interiors [49].

An intervention to sterilize regions for people and objects can be added, equipped with tools such as airlocks (SAS doors) that provide high-level contact with the outside, where the wall acts as a barrier to airborne pathogens.

Reducing surfaces and tools that are subjected to frequent touching by residents and visitors by activating remote control and voice control technologies, and by using self-cleaning materials. Automation controls can be considered for post-pandemic architecture, using remote connections via mobile applications to execute operations on a phone, laptop, or a central device connected to sub-devices for each apartment. The role of the “negative” skylight (in the upper part of the central area between the two apartments on the same floor) is to help sterilize the building by allowing daylight to pass through. It enhances ventilation through the proposed negative-pressure system, which directs the pipe to expel contaminated air from the intended isolation room (as clarified in the section and Fig. **6**).

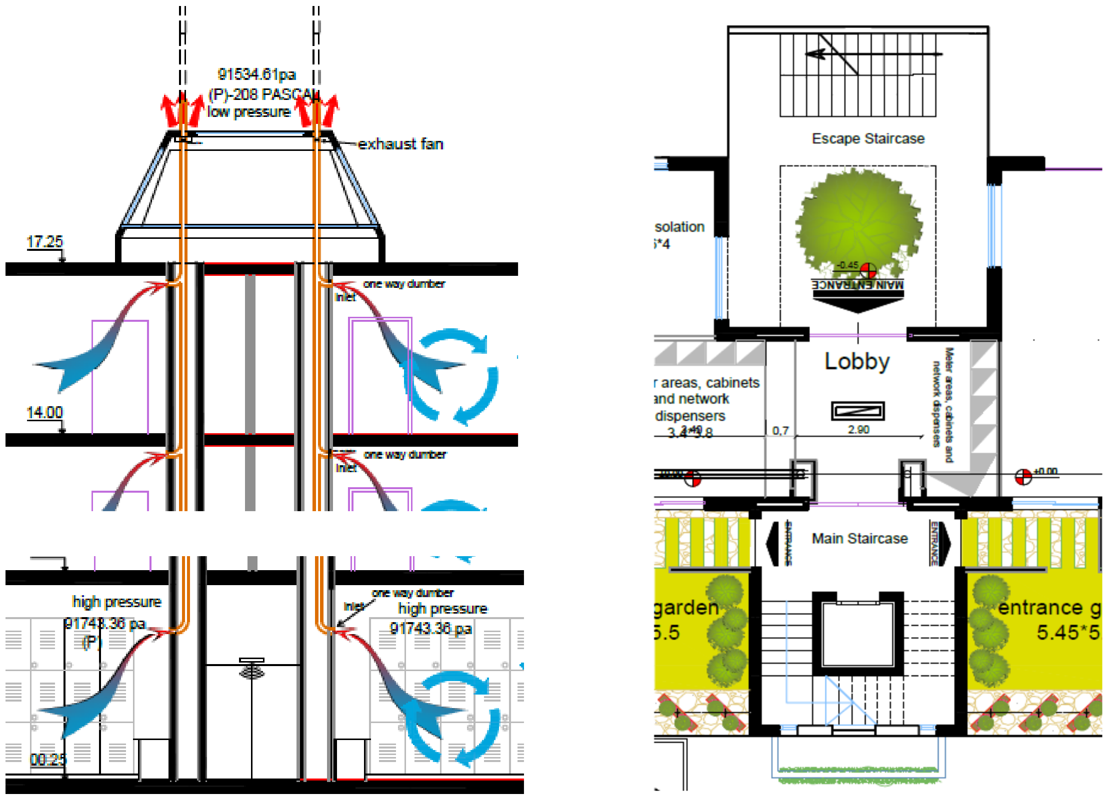

Figure 6: Skylight and negative-pressure system (left); staircases and lobby design (right). The left panel details the integrated "Immune System," where a central "negative" skylight provides natural sterilization through daylight while housing the AIIR extraction pipe. The right panel displays the foyer treatment: wind curtains and SAS air-lock doors to prevent the ingress of external pathogens.

The main stairs (bolded walls in Fig. **6**) should be designed with a width of at least 180cm per stair to ensure social distancing, with as much natural lighting and ventilation as possible. Vertical shafts, including stairwells and elevator cores, can act as conduits for aerosol transport between floors, requiring specialized air-pressure management [50]. For the elevator, it is recommended to reduce hand contact, increase single-trip speed to reduce the risk of infection, and limit the number of users at any given time. Technological advancements in vertical circulation now include HEPA filtration and UV-C sterilization within elevator cabins to continuously scrub the air of viral loads in high-occupancy buildings [51]. Furthermore, the integration of touchless smart-lift interfaces is essential to mitigate fomite-based transmission in high-density buildings [52].

The emergency stairs (safe path) should be treated as the main staircase in terms of materials. It could serve as a secure path for medical personnel and a passage for infected people. Thus, it shapes the safest stairway for use, as it is open to the outdoor environment and natural airflow.

The apartment is accessed through the entrance garden (Fig. **7**, right), which contains a transformable living wall. The entrance leads to the containment area (foyer), which includes a primary storeroom, a handwashing sink, and a receiving area for purchased materials. The foyer should include a hand-washing basin, as recommended by previous studies, to reduce the spread of viruses at the individual level (Fig. **7**, left). Good handwashing is a critical component in controlling the spread of many respiratory infections [28]. Modifying the space to accommodate a new function. This change is a revival of a custom that characterized buildings in the Far and Near East and in Islamic architecture: removing shoes before entering the house is prevalent in many societies and is evident in mosques, where differences in elevation among entrances, enclosed spaces, and exits are apparent (Fig. **7**).

With the development of technology, the introduction of remote work and distance education, the rise of electronic cities, and the strengthening of the idea of social distancing, these developments will inevitably affect the design of the guest room space. It will be smaller, converting part of this space into multiple areas, such as a work office equipped with the necessary remote communication tools. The provision of flexible, multifunctional spaces enables the rapid conversion of domestic areas into isolation or workspace areas, a key pillar of resilient housing design [53].

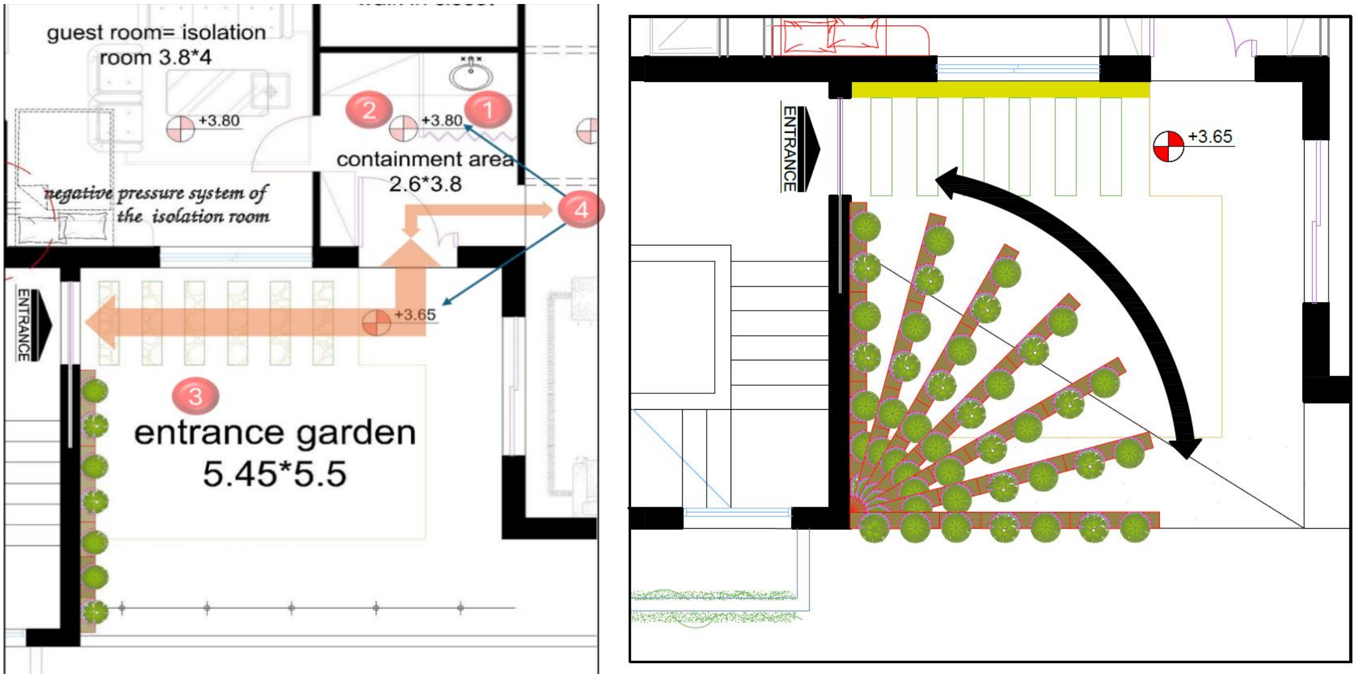

Figure 7: Foyer containment area (left), entrance garden with a transformable living wall (right). These architectural renderings illustrate the biological buffer zone at the unit's entrance. The foyer (left) incorporates differential floor levels for shoe disposal and a dedicated handwashing station, while the garden (right) uses healing landscapes to support resident psychological well-being.

The guest room is proposed for use as an isolation room during the spread of infectious diseases, as people avoid receiving guests during such periods, if not governmentally prohibited, to break the chain of infection. Thus, the empty guest room becomes an airborne infection isolation room (AIIR), which should have its own bathroom. This room has a direct, unobstructed connection to the escape stairway (Fig. **8**), providing a safe path.

Promoting the concept of cross-ventilation to protect against disease transmission in space design, a relationship between the kitchen and living spaces, with the entrance passing through a transitional space (the containment space) for sterilizing foods and purchases, with a strong connection to the natural landscape and the apartment's balconies from the other side. This also allows the combination of different daily activities during home confinement (Figure).

At least one bedroom must be connected to an outdoor terrace or veranda to provide natural ventilation and control wind movement, preventing the spread of infection (Fig. **9**). The ventilation and air conditioning system for one of the rooms is isolated from the rest of the system to prevent the spread of infection via the infected person's respiratory droplets.

The implementation of a negative-pressure isolation room (AIIR) in a residential context addresses the 'critical gap' in the architectural literature identified by Kalu *et al*., who noted that such strategies had previously been reserved for healthcare facilities. In contrast to standard residential HVAC systems, which Dietz *et al*. warn can facilitate the growth and spread of human-associated microorganisms, the model's integrated AIIR-skylight system actively expels contaminated air via pressure differentials (Fig. **10**). This finding is supported by CFD simulations, which confirm that maintaining negative pressure in isolation zones is a more effective aerosol management strategy than the simple 2-meter social distancing recommended in earlier pandemic guidelines.

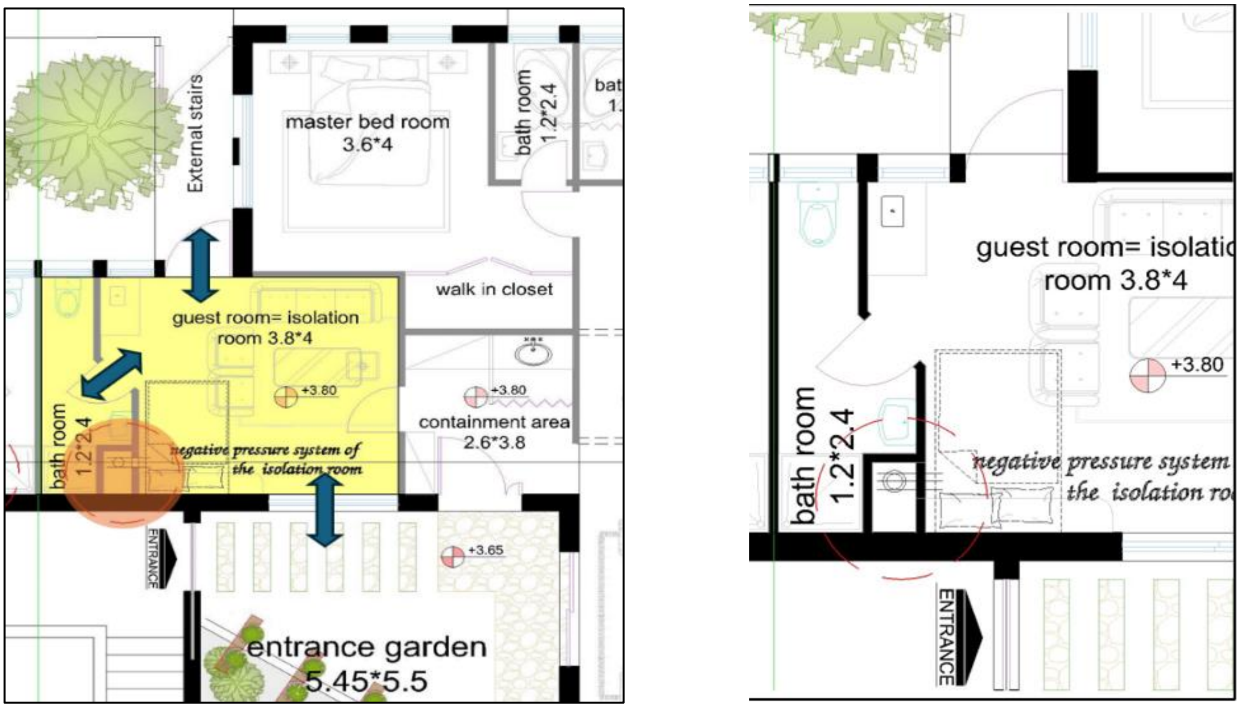

Figure 8: Guest/isolation room (in yellow, left), connected to the garden and the escape staircase. The proposed negative-pressure room in the bathroom zone (on the right). This figure demonstrates the flexibility of the traditional guest room, reconfigured here as a self-contained AIIR with its own bathroom. The right panel shows the technical details of the negative-pressure duct, which utilizes pressure differentials to actively expel contaminated air directly to the building's exterior.

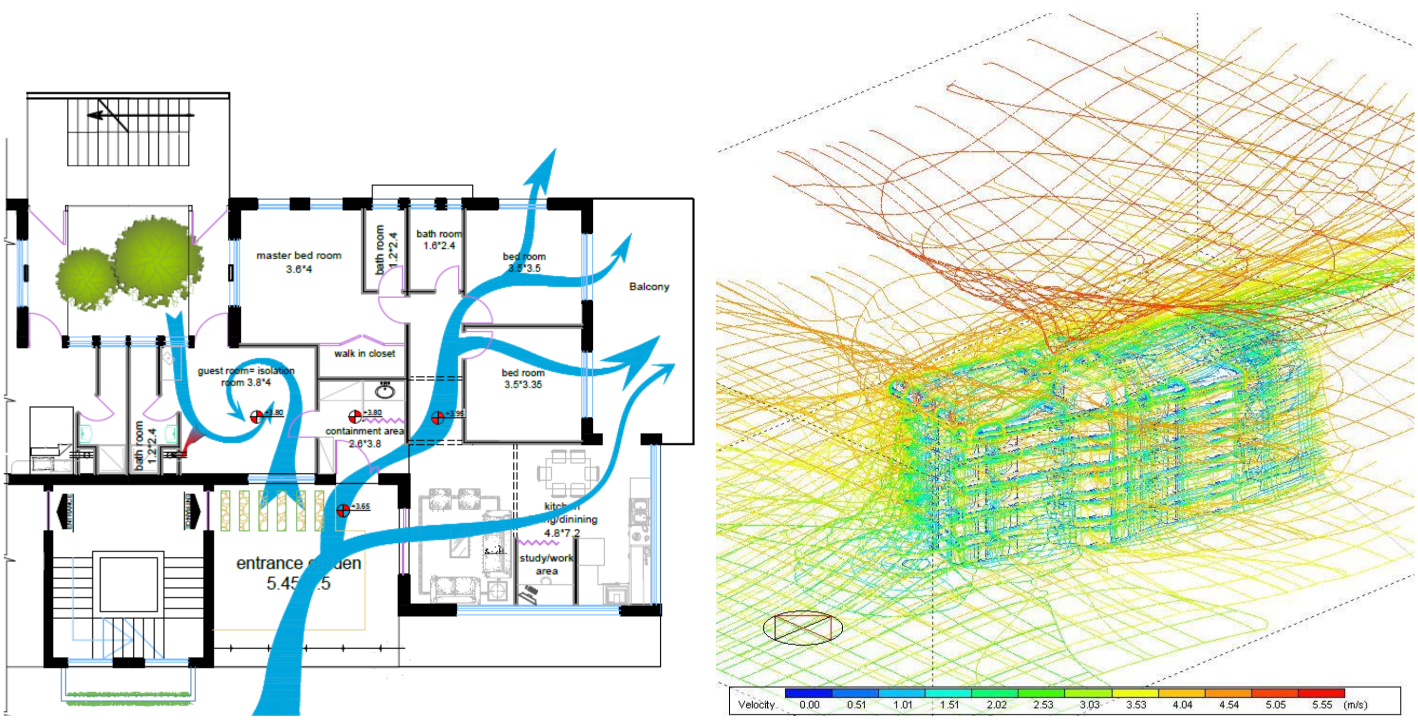

Figure 9: Cross-ventilation through the indoor spaces (left) and external CFD (right). The entrance balcony actually improves IAQ through cross-ventilation. This figure presents Computational Fluid Dynamics (CFD) simulations validating the efficacy of the entrance garden and balconies in promoting cross-ventilation. The analysis confirms that these transitional spaces significantly improve Indoor Air Quality (IAQ) by ensuring a continuous flow of fresh air, which reduces viral load concentrations.

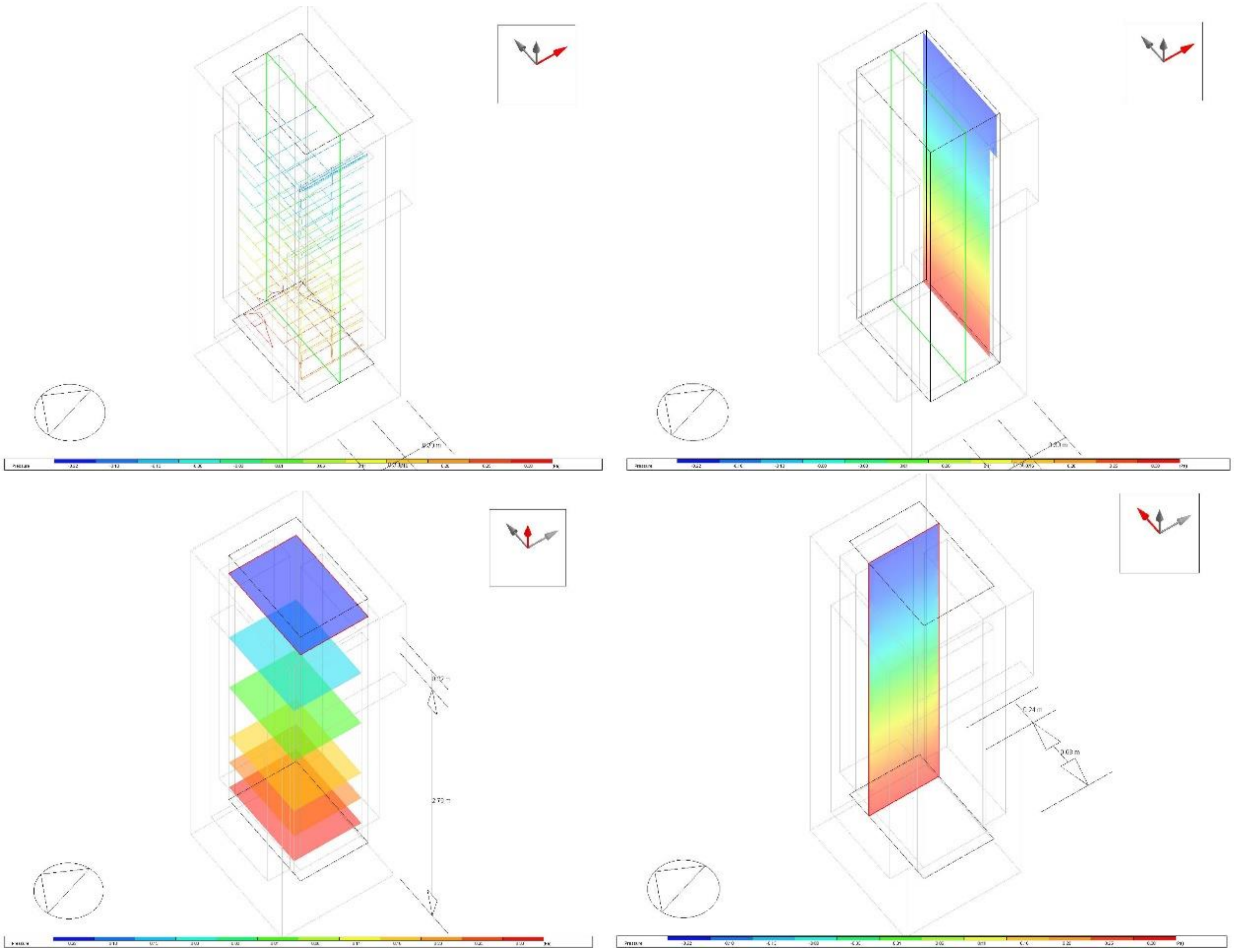

Figure 10: The pressure difference inside the negative pressure room. This simulation result illustrates the maintained pressure gradient within the isolation suite. It visually confirms that the architectural response (the AIIR-skylight link) effectively prevents the leakage of infected respiratory droplets into adjacent communal living spaces.

The novelty of the model lies in its integrated Immune System. The negative-pressure isolation room (AIIR) is not a standalone feature; it is linked to the negative skylight, which uses pressure differentials to expel contaminated air. Simultaneously, the Safe Path escape staircase serves a dual function as a secure egress for infected residents and a dedicated entry for medical personnel, effectively breaking the chain of infection in shared vertical circulation.

A significant point of critical analysis is the 'Safe Path' escape staircase, which mitigates the risk of vertical shafts acting as 'conduits for aerosol transport' between floors—a danger highlighted by Brown and Davis. While standard multi-unit designs often feature shared elevator cores that increase the risk of fomite-based transmission, our model introduces a dedicated medical entry/egress path. This intervention distinguishes our work from general residential design trends by creating a functional separation between infected and healthy traffic, thereby addressing the complexities of airflow in high-density buildings noted by Hwang and Lee.

The COVID-19 pandemic demonstrated that residential architecture must evolve to keep pace with rapid developments in telehealth and remote care. Findings from this study indicate that the traditional "guest room," often underutilized in Palestinian apartments, is an ideal candidate for conversion into a dedicated Telemedicine Room. The transition toward residential-based healthcare requires specialized infrastructure, including high-speed connectivity and acoustic privacy for remote triage [54]. By equipping this space with its own bathroom and a direct connection to a "safe path" escape staircase, the room functions as a self-contained medical environment that prevents direct physical contact with other residents while ensuring continuous patient care. This spatial reconfiguration is supported by recent evidence indicating that telemedicine significantly increases patient access and satisfaction during viral outbreaks, thereby reducing mortality rates by enabling remote triage and vital-sign monitoring.

Beyond a single room, the architectural interventions proposed in this model transform the entire apartment into a sophisticated remote healthcare node—a decentralized extension of the public health system. This transformation is achieved through a multi-layered "Immune System" of design interventions:

- Contaminant Mitigation: The introduction of an entrance garden and foyer containment area acts as a transitional sterilization zone, preventing external pathogens from entering the primary living environment.
- Aerosol Management: The integration of a negative-pressure isolation system (AIIR), linked to a central "negative" skylight, ensures that contaminated air is actively expelled from the isolation room rather than circulating through shared HVAC units. Computational fluid dynamics (CFD) simulations confirm that maintaining a slight negative pressure in isolation zones effectively prevents the leakage of contaminated air into adjacent living areas [55].
- Secure Medical Access: By designating the emergency stairs as a secure path for medical personnel, the building manages the "Safe Path" for healthcare providers to reach the remote node without exposing other residents in the main staircase to infection.
- Technological Integration: The use of touchless sensing, voice response, and remote-control technologies minimizes contact-based transmission, allowing the apartment to operate as a digitally-controlled, self-sterilizing environment. Regarding material efficacy, our study's emphasis on copper-based alloys and self-cleaning surfaces aligns with clinical findings indicating that these materials significantly reduce the half-life of respiratory viruses compared with standard stainless steel or plastic. Furthermore, the integration of touchless smart-lift interfaces and wind curtains represents a shift toward the 'Smart Building' paradigms advocated by Wainwright and Thompson. By synthesizing these technological tools with architectural layout changes, the research moves from a focus on individual behavior to a systemic 'Integrated Immune System' for the built environment.

Although the proposed architectural interventions require additional initial investment, they are designed to be practically feasible by using existing residential layouts and passive strategies, as follows:

- Cost Implications and Design Justice: The study acknowledges that transforming standard apartments into 'health-resilient' units requires higher expenditures for materials and technological systems. However, these costs are offset by 'Design Justice', which aims to provide affordable, healthy housing for marginalized communities disproportionately affected by infection risks in high-density cities. To minimize costs, the model utilizes passive design strategies and reconfigures underutilized existing spaces—such as the traditional Palestinian 'guest room'—into multi-functional isolation or telemedicine nodes, thereby avoiding the need for expensive additional square footage.
- Real-World Applicability: The model is rooted in the actual architectural context of the Hebron region, utilizing the prevalent 'Housing A' typology (two apartments per floor) as its base. Its applicability is further enhanced by its presentation as a Procedural Guide (Table **1**), intended for adoption by local authorities and the Ministry of Health as a mandatory annex to building permit laws. This legislative approach ensures that health-resilient features become standardized across all housing sectors, rather than remaining a luxury for high-income segments.
- Implementation Challenges: Despite its feasibility, several challenges remain. The transition toward decentralized healthcare nodes in apartments faces technical obstacles, including the need for specialized equipment, reliable high-speed internet for telemedicine, and robust data security protocols to protect patient privacy. Furthermore, implementing these systems in existing apartments requires a degree of flexibility and interest from property owners, which may necessitate government-led incentives or subsidies.

4. Conclusions and Recommendations

The logical framework of this study is rooted in the triangulation of findings from three distinct stakeholder groups, ensuring the proposed model is scientifically, technically, and socially grounded.

- Findings from Virology Specialists (Group 1): Established the biological baseline for the design, emphasizing that negative-pressure isolation (AIIR) and the use of antimicrobial materials (such as copper-based alloys) are critical to managing aerosol dispersion and reducing viral half-lives on surfaces.
- Findings from Engineering Experts (Group 2): Validated the technical feasibility of the integrated 'negative' skylight and duct system, confirming through simulations that passive ventilation and wind curtains can effectively manage indoor air quality while reducing energy dependency.
- Findings from Inhabitants (Group 3): Highlighted the psychological necessity for transitional entrance gardens and flexible spatial layouts—specifically the conversion of guest rooms into self-contained healthcare nodes—to mitigate the stress and functional deficiencies of long-term home confinement.

By synthesizing these multi-disciplinary perspectives, the study moves beyond temporary crisis-response to propose a permanent architectural 'Immune System' that balances clinical safety with resident well-being." A set of interventions was proposed to modify and update the functional framework of apartment buildings to reduce infections from airborne and contact-based diseases by adhering to specifications and directives for materials and surfaces and by employing technological developments in design that effectively reduce the spread of infection in multi-apartment buildings. During periods of infection, there is a need to protect public health and provide safe corridors for medical teams to enter and exit multi-apartment buildings with minimal risk. Therefore, there is a need to adopt the results of this research on the proposed intervention model, as summarized in Table **1**, which serves as a Procedural Guide.

The integration of automated infection-control measures is paramount to future-proofing multi-unit housing against emerging pathogens [51]. Dependently, the findings suggest that health resilience should no longer be a voluntary design choice but a mandatory requirement for building permits. Dependently, this research recommends that local authorities and the Ministry of Health adopt the 'Procedural Guide' (Table **1**) as a binding annex to civil defense and building licensing laws. This legislative shift is essential to ensure that 'Building Immunity' becomes a standardized feature in affordable housing, rather than a luxury for high-income segments. Adopting personalized ventilation strategies is essential for managing viral risks in shared multi-unit environments [58].

Framing the apartment as a healthcare node aligns with the emerging global trend toward self-sufficient, health-resilient housing. As urban centers move toward distance learning and remote work policies, the apartment must serve as a tool for crisis management. This research provides a procedural guide for licensing institutions, arguing that these health-security features should be mandated in strategic urban plans and building codes to ensure that marginalized communities have access to the same level of "Building Immunity" as high-income sectors. Finally, prevention and protection measures must be formally adopted in both workplace and residential settings to build immunity [59].

This research makes three primary contributions to the field of health-resilient architecture:

- The Integrated Immune System Model: Unlike temporary crisis-response measures, this study introduces a permanent, linked network of architectural interventions—including the negative-pressure AIIR technically coupled with a central skylight and the 'Safe Path' dual-function staircase—that effectively breaks the chain of infection in shared high-density environments.
- Multidisciplinary Validation: The framework bridges the gap between clinical data and spatial design through a three-phase validation process involving virology specialists, sustainable engineering experts, and inhabitants.

- Legislative Tool for Design Justice: The study culminates in a Procedural Guide (Table **1**) designed for local authorities to standardize health resilience, ensuring that 'Building Immunity' is a mandatory feature accessible to marginalized communities rather than a luxury for high-income sectors.

Table 1: Summary of the proposed interventions for the apartment.

Space/ System	Intervention
Entrance lobby of the residential building	Installing a wind curtain at entrances to prevent the ingress of pathogens and dust Providing a storage area for online and delivery purchases. Providing a sterilization area for things and people, such as an Airlock (SAS door). Use a white wall to trap airborne pathogens. Reducing surfaces and tools frequently touched by residents and visitors by activating remote and voice-control technologies and using self-cleaning materials.
Elevator	Reduce touching with hands. Increase the speed of a single trip to reduce the possibility of infection.
Main staircase	The width of the coaster must be at least 180 cm to ensure social distancing. Use natural lighting and ventilation whenever possible.
Emergency stairs	Treating it as a central staircase. Therefore, it should be the safest path for medical personnel and the passage of infected individuals, and the safest stairway for outdoor use.
HVAC system	Preventing shared HVAC units at the building level.
Mechanical systems	The apartment water supply network must be divided into two parts: first, the drinking and bathing water network, which must comply with World Health Organization standards. Secondly, the cleaning and sterilization water network must comply with the previously mentioned standards, with additions appropriate for private use, including the recommended sterilizer percentages.
Skylight	The negative skylight sterilizes residential apartment rooms by activating the proposed negative-pressure system, which evacuates contaminated air from the isolation room through the pipe.
Apartment entrance	Entrances - the containment area - must contain additional space for sterilization and cleaning (for people and things), for removing shoes and coats, washing hands, and receiving purchased materials. Many techniques can be used; depending on the material, water and steam are feasible. The entrance must also include a handwashing basin, as proper handwashing is critical to controlling the spread of SARS-CoV-2, other coronaviruses, and many respiratory infections [28]. Making a difference in levels between entrances, containment spaces, and exits.
Guest room	My guest room serves as an isolation room for infectious diseases. It must be attached to its own bathroom. Strong and direct connection with the escape stairway. Converting part of the guest room area into a place for distance learning for all levels.
Kitchen Dining room Living space	Promoting the concept of cross-ventilation for the purpose of protecting against disease transmission in space design. The relationship of the kitchen with the entrance is through a transitional space - the containment space - for sterilizing foods and purchases. A strong connection to the entrance garden and the apartment's balconies.
Bedrooms Bathrooms	One of the rooms must have a private bathroom. At least one bedroom should be connected to an outdoor terrace or balcony. The HVAC and AC systems in a single room should be isolated from the rest of the system to prevent the spread of infection via infected droplets. The use of technology in these spaces, specifically for sterilization with ionizing radiation, ultraviolet radiation, and innovative nanotechnology-treated materials that self-clean [56]. Innovative nanotechnology-treated materials, such as titanium dioxide (TiO_2) coatings, provide a persistent antimicrobial effect by degrading pathogens on building surfaces through photocatalytic reactions [57].
Terraces and balconies	Creating an entrance garden that offers privacy while remaining separate from the apartment. It contributes to the provision of productive and protective living walls.
Negative pressure room	A negative-pressure room (duct) is included alongside the isolation room to enhance ventilation during pandemics and periods of infection.

Despite its contributions, this study has several limitations:

- Geographical and Climatic Focus: The model and simulations were specifically developed for the Hebron Governorate and its temperate mountainous climate; therefore, the results may require calibration for regions with different environmental conditions.
- Retrofitting Challenges: While the model provides a standard for new 'Housing A' developments, the implementation of these complex systems in existing built apartments faces significant obstacles regarding structural flexibility and the need for government-led financial incentives.
- Technological and Security Barriers: The proposed transition to decentralized healthcare nodes relies heavily on telemedicine infrastructure, which currently faces challenges such as inconsistent high-speed internet access and data security concerns for sensitive patient information.

Future studies could expand upon this framework in the following areas:

- Long-Term Performance Monitoring: Empirical research is needed to monitor the real-world efficacy of self-cleaning materials and negative-pressure systems over extended periods within occupied residential settings.
- Scalability to Diverse Typologies: Further research should test the adaptability of the Procedural Guide for different building typologies beyond the standard multi-unit apartment, including student housing and mixed-use urban blocks.
- Socio-Economic Impact Analysis: Investigative studies into the cost-benefit ratio of mandatory health-resilient infrastructure would provide essential data for policymakers to justify the initial investment against long-term public health savings.

Ethical Approval and Consent to Participate

This study was conducted in accordance with rigorous ethical standards and obtained formal approval from the Palestinian Ministry of Health for all participant interviews. Research data were gathered from 56 stakeholders—including medical specialists, engineering experts, and residents—with informed consent and voluntary participation. To ensure confidentiality and objectivity, all qualitative data underwent structured manual coding and thematic analysis, which anonymized individual responses while identifying key design patterns. Furthermore, professional consultations with specialists were conducted via secure digital platforms to maintain safety protocols while bridging the gap between clinical health data and architectural design.

Conflict of Interest

The authors declare no conflict of interest.

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