Investigation of the Space in Response to the Conditions Caused by the Pandemics and Presenting Five-Scale Design Guidelines to Adapt and Prepare to Face the Pandemics

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Abstract—Historically, pandemics in different periods have caused compulsory changes in human life. In the case of COVID-19, according to the limitations and established care instructions, spatial alignment with the conditions is important. Following the outbreak of COVID-19, the question raised in this study is how to do spatial design in five scales, namely object, space, architecture, city, and infrastructure, in response to the consequences created in the realms under study. From the beginning of the pandemic until now, some changes in the spatial realm have been created spontaneously or by space users. These transformations have been mostly applied in modifiable parts such as furniture arrangement, especially in work-related spaces. To implement other comprehensive requirements, flexibility and adaptation of space design to the conditions resulting from the pandemics are needed during and after the outbreak. Studying the effects of pandemics from the past to the present, this research covers eight major realms, including three categories of ramifications, solutions, and paradigm shifts, and analytical conclusions about the solutions that have been created in response to them. Finally, by the consideration of epidemiology as a modern discipline influencing the design, spatial solutions in the five scales mentioned (in response to the effects of the eight realms for spatial adaptation in the face of pandemics and their following conditions) are presented as a series of guidelines. Due to the unpredictability of possible pandemics in the future, the possibility of changing and updating the provided guidelines is considered.

Keywords—Pandemics, COVID-19, spatial design, ramifications, paradigm shifts, guidelines.

I. INTRODUCTION

THROUGHOUT history, several infectious diseases with different pathogens (viruses, bacteria, etc.) and various transmission routes have spread and led to pandemics [1]. Few phenomena have shaped our societies and cultures as deeply and as permanently as infectious diseases. Some effects are limited to the duration of the pandemic, while other destructive and challenging impacts persist for a longer time. Due to the sudden occurrence of pandemics and societies' unpreparedness, many crises have happened. Paradoxically, in some cases, pandemics have also motivated innovations and advances in science, economy, and political systems [2].

In the last 20 years, the emergence of new diseases has demonstrated the unpredictable powers of nature [3]. As globalization accelerates, viral outbreaks, which used to happen locally and endemically, are now rapidly transcending borders in a matter of hours, turning into epidemics and pandemics, and becoming a major global public health threat. While the first human case of COVID-19 was reported in Wuhan, China, in December 2019, the World Health Organization declared a public health emergency with an international concern on January 30, 2020, and by March 30, 2020, the outbreak had become a pandemic [4]. Since then, it has extended itself over the entire globe. Various dimensions of society faced challenges and crises, forcing them to change and adapt to new conditions.

With numerous transformations and the continuation of paradigm shifts after this widespread global outbreak, the post-COVID-19 era may be recognized as a lasting period that requires flexibility and adaptability of the spatial realm. We assume that if the affected domains had been ready to accept and face the pandemic, severe and irreparable damages like what happened during the COVID-19 pandemic would not have occurred or would not have disrupted the daily lives of urban citizens to such an extent. Thus, the question posed in this research regards the changes necessary for the spatial realm (with its five scales of infrastructure, urban spaces, architecture, space, and object) to adapt to life in the post-COVID-19 era and to prepare itself for future pandemics to mitigate the adverse effects, intensity, and distribution speed of pandemics with revision and foresight in design.

Accordingly, in this research, our lessons of pandemics are investigated through an archival study in a three-dimensional analysis in ramifications, solutions provided by communities, and paradigm shifts. In addition, the demographic, political, economic, technological, ecological, social, lifestyle, and spatial realms have been considered for analytical purposes so as to find and use the data that has a spatial aspect in order to achieve the design suggestions.

So far, the influential factors in the process of spatial design have been considered to be some factors such as human activities and standards, climatic and geographical conditions, demographic, social, and economic issues. At present, however, it is necessary to introduce a responsible foresight approach to avoid undesirable future events [5]. Thus, the conditions

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resulting from pandemics and their lessons should be considered in the design process. Therefore, using the analytical tool, the paradigm shifts related to spatial realms are selected to achieve design suggestions. The ideas are presented based on three sources: (1) previous solutions and spatial paradigms that have changed in pandemics to date, (2) ideas suggested by users and designers in the COVID-19 pandemic, and (3) ideas designed and proposed by the authors of this paper. The end goal of the study is to use physical space and its central role to help decrease the disruption faced by the humans and mitigate the intensity and versatility of the new viral outbreak.

II. METHODOLOGY

Step 1: Archival Study Based on Criteria

As mentioned earlier, the spread of diseases and their transformation into pandemics have occurred throughout history. Despite the consternation of many societies in the face of the COVID-19 pandemic, it has not been the only one. Considering the diversity and differences in the origin of the diseases and their transmission, it seems that pandemics have similarities in the model of their spread and their impact on various aspects of human life, nature, and so on. Therefore, in the first stage an archival study was conducted to respond to the questions raised in this research.

Samples and data selection manner were as follows.

1. Samples

Study period: Considering the fact that comprehensive and accurate information on Before Common Era (BCE) has not been documented and available and because the human lifestyle and medical science in that period were very different from the present time, the period of Common Era (CE) was considered as the time criterion for the sample selection.

The impact of infection and death: During the CE period, all the pandemics (epidemics worldwide), as well as epidemics with more than 5 million deaths, were selected for the study.

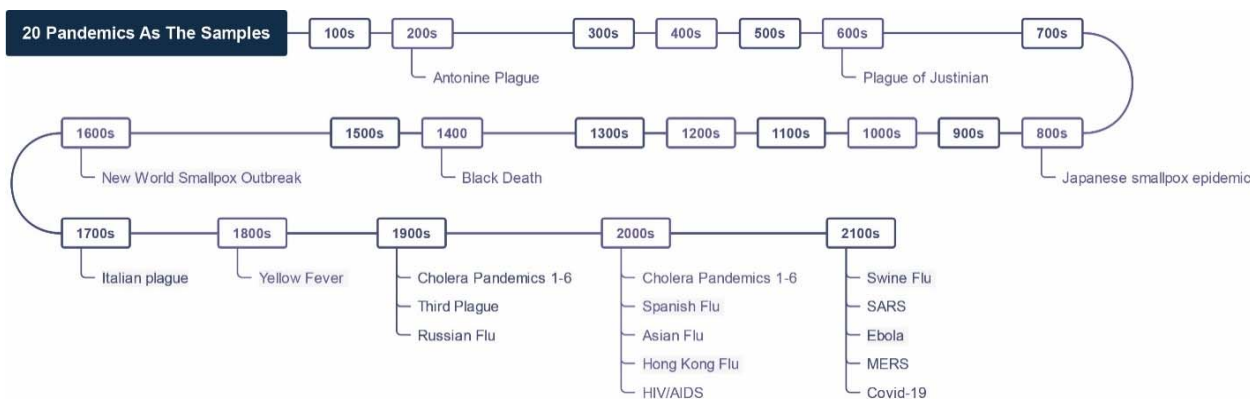Finally, using the given considerations, 20 pandemics were selected as the primary research samples.

Fig. 1 Timeline of 20 pandemics that have been selected as the samples of the archival study

Criteria for studying and reviewing the selected samples to achieve initial data: These included (1) geographical and social origins of the outbreak, (2) time of occurrence and period of outbreak, (3) sphere of influence of the outbreak, (4) order of outbreak and spread of the virus in the affected area, (5) factors affecting the origin of the disease, (6) identification and examination of significant coincidences with historical events, (7) morbidity and mortality rate, (8) world population at the time of the pandemic and percentage of morbidity and death toll relative to the world population.

2. Data

The lessons learned from pandemics were considered as research data: The last stage of the archival study was to collect the effects of pandemics and the changes caused by the outbreak in different domains as initial data to classify in the next level of research.

Step 2: Analysing the Archival Research

By conducting the archival study, we found firstly that all the pandemics, in relation to spread and the severity and the mortality rate, have led to the ramifications that are considered both challenging and potentially fruitful. Therefore, to respond to the challenging ramifications, some transformations have been made in time and place, which are known as solutions. In terms of their relation to this research, these solutions are categorized into three steps: (1) reconstructing a phenomenon exactly like its original form, (2) considering the changes and updating them, (3) designing and proposing. As the result of the consequences as well as strategies used to solve the problems, the common patterns have changed, and these changes, both during and after the outbreak, are repeated to form the paradigm shifts. Thus, in order to analyse the initial data, a triple analytical visualization tool was designed according to Fig. 2, and 101 of the lessons learned from the pandemics and the relationship between them were examined in the eight realms as sub-factors of the tool.

The description of this part of study is available in a copy of the TUIC-101 series at [6].

The three main factors are ramifications, solutions, and shifts, respectively, and the eight realms separating the studied data are sub-factors. Data achieved from selected pandemics based on their type and causal relationships between them were

analysed using this tool.

		Demographic	Political	Economic	Technological	Ecological	Social	Lifestyle-based	Spatial
Ramifications	Challenges	Data	Data	Data	Data	Data	Data	Data	Data
	Potentials	Data	Data	Data	Data	Data	Data	Data	Data
Solutions	Concrete	Data	Data	Data	Data	Data	Data	Data	Data
	Abstract	Data	Data	Data	Data	Data	Data	Data	Data
	Newly Proposed	Data	Data	Data	Data	Data	Data	Data	Data
Shifts	During the pandemic	Data	Data	Data	Data	Data	Data	Data	Data
	Post-pandemic	Data	Data	Data	Data	Data	Data	Data	Data

Fig. 2 Triple Analytical Visualization Tool

Step 3: Identifying Paradigm Shifts with the Rather Spatial Aspect

After performing the proposed analysis for 101 cases of selected pandemics in the first phase of the research, the paradigm shifts with a definite or probabilistic spatial aspect were selected. If the challenging ramifications or solutions applied to solve the pandemic crisis problems had led to a change in space, i.e., if the space (in each of the five scales proposed) was similar to the space before the crisis, the challenge or its severity would be avoided. Accordingly, by summarizing that paradigm shifts and how they act, the first step was taken for design suggestions to change and improve the body space to adapt to life in the post-COVID-19 era and to prepare itself for future pandemics to mitigate the adverse effects, intensity, and speed of pandemics.

Step 4: Providing Design Guidelines

After the three foregoing steps, spatial practices are proposed, which, as a paradigm shift, could control the problems following the distribution of a present or future pandemic by being applied in the spatial realm.

The suggested practices or guidelines are presented in five main headlines based on the scale: (1) Infrastructure, (2) urban, (3) architecture, (4) space, and (5) object. Ten guidelines are provided for each scale. Each of the guidelines is placed in one of the categories based on the level and the origin of the concept:

Level of design: In this research, some guidelines are aimed at reforming design philosophy and looking beyond mere ideas with common attitudes. The others are new design ideas and styles that act as guidelines in accordance with common philosophies of life.

Origin of concept: The concepts can originate from (1) previous pandemics and their paradigm shifts, (2) suggestions by users and designers in the COVID-19 pandemic period, and (3) proposals by the authors of this research.

III. RESULTS AND DISCUSSION

A. Infrastructure

1. Changing the Notion of Metropolis

One of the long-term consequences of the pandemics in urban development is the emergence of a new wave of sub-urbanization. After imposed traffic bans, restriction of social interactions, and spread of online streaming events, many people avoid living in densely populated cities, thus contributing to the decentralization of metropolitan areas. In other words, compared to the past, work, education, and entertainment are less temporal and spatial [7]. Therefore, with the unplanned changes in the concept of the metropolis, scholars such as [8]-[10] suggest that it is necessary to consider the following changes in the design of urban infrastructure to respond to the new norms:

- Reconsideration of suburban and intra-city transportation network design.
- Flexibility in the design of the architectural volume and the allocation of functions in urban zones (each zone with its predominant focus also includes services to annul the necessity of visiting distant destinations and using motorized transportation, hence decreasing the likelihood of an outbreak).
- Reduction of the number of large-scale commercial and recreational spaces.
- Expansion of residential areas in small towns and suburbs.

2. Development of the Internet and Electronic Networks

Restricting the attendance of people in many places led to an acceleration of the digitization of many activities that required the physical attendance of individuals. Many daily activities such as education, shopping, and working were nearly 100% online in peak periods. After that, this level of virtual life became somewhat the new norm. Given that electronic and internet networks are located in the physical context of cities and need to be developed and grown, it is obvious that the physical space of infrastructure as a platform for these networks should be able to respond to a new level of digital and

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networked services. Therefore, it is necessary to consider factors such as flexibility, redundancy, versatility, etc., in the design of relevant infrastructure [11].

3. Improvement of Smart Cities and the Ability to Screen the Population in Order to Constrain the Transmission

Since monitoring is used to control urban challenges such as crime investigation, climate change, air and noise pollution measurement, vegetation care, etc. [12], [13], it seems that this method can also be used to control the pandemics and could be effective by detecting outbreaks in different areas and tracking the infection pattern both temporally and spatially. By equipping infrastructure networks to monitoring devices and tools that can control the body temperature of people, the gravity and extent of the spread or the way the disease is spread in urban areas can be observed. Thus, in addition to controlling and managing the distribution of people, other contributing factors could also be realized in this issue. Regarding the implementation of this proposal, we can mention the study of environmental parameters (temperature, humidity, pressure, and light) by WSNs in New Jersey applied by Rashid and Rehmani [13]. By adding new sensors to detect body temperature or other symptoms of infected people, the potential of smart cities and screening can be used more.

The proposed method is top-down management, technically based on AI and authority. However, this policy can also be executed by raising public awareness and knowledge of the importance of monitoring and control by activating control in personal smart devices, such as cell phones, smart watches, etc. Research in this area during the pandemic proves that intelligence will have the best results if it is a combination of AI and human-centred methods [12], [13].

4. Incentive Policies for Private-Car-Based Transportation

COVID-19 reinforces car-based travel behaviours, because the use of urban public transportation means such as subways and buses has decreased during the outbreak due to non-compliance with the requirements of the pandemics. After passing the peak of the pandemics, the rate is still 75% lower than expected [14]. Even after vaccination, people seem to be afraid of getting close to each other and feel uncomfortable on public transport. Given the evidence that frequent pandemics have increased in recent decades, this "shock" may become a permanent state [15]. Thus, much of this need will be met by private motor vehicles. The infrastructure policies for this type of travel, especially at the intra-city scale, will need to grow and strengthen. This, in turn, will have consequences for fuel consumption, traffic congestion, frequency of accidents, and air pollution. As a result, more vulnerable communities may be disproportionately affected [16], [15].

5. Improvement and Development of Bicycle Routes and Incentive Policies for Cycling

More than 90% of the countermeasures in the field of mobility were about the overall reduction of commuting and later the increase of active trips due to the ability to maintain social distance in movement and avoid congestion in short distances. Active travel simply means making journeys in physically active ways - like walking, wheeling, cycling, or scooting. Thus, "active and non-motorized mobility" gained new momentum to become a major mode of transportation in the city [14], [17]. Cycling, for example, has become more popular in many cities, including Brussels. The city of Brussels has implemented a 24.9 km long bike lane, a 23.4 km long traffic calming road, and a 5.15 km entrance restriction for private cars, prioritizing pedestrians and cyclists. As a result, cycling has increased by 44% in 2020 compared to 2019 [18]. Therefore, it is necessary to develop cycling-only routes in designing local and trans-local routes and access. In this regard, traffic calming measures and initiatives to improve road safety through the allocation of road space to the bike path, speed restrictions, car bans, and physical design of roads with a preference for bicycles are necessary supplements to support the investment in cycling route infrastructure. Without making the roads safer for bicycles and actively preventing accidents, mere cycling measures cannot be successful. This solution is only to promote this method of transportation and does not necessarily replace other usual methods. Due to unfavourable weather conditions, hilly topography, lack of parking space in every place, and cultural barriers to bicycling, in many communities, there is no public and all-time access to this measure [19]-[21].

6. Development and Improvement of Walkways

Decreased participation in outdoor activities as a result of social distancing can negatively affect mental well-being [22]. This isolation (especially during peak periods) leads to lower levels of social interaction and higher levels of stress, boredom, and depression [23]. In peak periods, indirect, short-range, wandering trips are more popular because there are not many travel destinations. This means that walking and running are done as recreational activities and being exposed to the environment and landscapes, leading to maintaining mental well-being and experiencing positive emotions [24], [25]. Therefore, in designing the infrastructure of urban zones, it is necessary to give more attention to designing walkways, as these were mostly considered sports activities before the threat of pandemics but were located in sports facilities or parks.

7. Reevaluation of the Waste Separation and Disposal Procedure

Statistically, each COVID-19 patient produces 3-4 kilograms of waste per day. The increase in the total volume of waste first threatens the waste collection staff and health care workers, and then the environment and the general public. This issue requires revision and modification of the waste disposal system. In this regard, the following solutions are proposed at the infrastructural scale:

- Separate disposal of infectious and non-infectious wastes with colour classification in medical and non-medical centres.
- Disinfection of waste at the time of disposal and temporary storing procedures in medical centres.
- Separate transportation of infectious and non-infectious waste.

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- Disposal of waste away from environmental elements, especially water.

This way, the expansion of the outbreak and pollution through waste is controlled to some extent, the recycling rate is maintained as high as possible, and the damage to the environment is prevented [26]-[28].

8. Introduction and Further Development of Green Spaces

By restricting the attendance in closed recreation centres, the tendency of people to use green spaces to moderate the psychological damage caused by social isolation has increased. This has been the case in previous pandemics, too. After the second Cholera outbreak in New York, the necessary planning was undertaken in the city's Central Park. In addition, urban regeneration plans, new parks, and open spaces in Mumbai and Melbourne were created in response to the hardships of the First World War and the Spanish Flu [29]. Therefore, it is necessary to pay more attention to designing urban green spaces as a part of natural and sustainable recreational space (as compared to closed recreational space) in the post-COVID-19 era.

Dividing the green space (based on the use and type of management) into three categories (i.e., designed green spaces, forest parks, and organic green spaces), the most appropriate trend to be observed is to make less use of designed spaces in parks (even benches) and more use of lawns and more flexible and open spaces. Many people also admit that they did not notice green spots near their homes before the epidemics, but as a result of the quarantine and restriction of closed spaces, they started to use these green spots on roads or residential zones [30]-[32].

To implement this policy, the following actions are required:
- Increasing the standard of green space per capita.
- Balancing green space distribution in the city.
- Prioritizing functionalism in the design of parks over formalism [33].

9. Health Improvement and Urban Equality (in Urban Services) in Slums

The unsupportive approach of the city administration regarding slums and the unfavourable welfare situation of these areas and other problems – such as weak health care (lack of adequate sanitation), high population density, lack of physical distance between people, and low level of awareness in these communities and (sometimes) more air pollution – have exacerbated pandemic crisis and has even led to the spread of some variations of these diseases from these areas [34], [35]. Consideration of these facts confirms the crucial and essential importance of addressing these areas at the infrastructure and long-term planning levels. In this regard, the following suggestions are presented:
- Verifying demographic information and health status of individuals.
- Shielding on different surfaces of houses and urban blocks.
- Increasing active community participation (NGOs) to improve the situation in these areas.
- Promoting awareness and education using urban media and sponsored environmental graphics.

B. Urban

1. Development of Open Recreational Spaces and Their Balanced Urban Distribution

Simultaneous with restrictions and the fear of attendance in closed spaces, the per capita allocation of open recreational and sports spaces should be reviewed. In any city and neighbourhood with any per capita of open recreational and green spaces, neighbourhoods – especially residential neighbourhoods – should be able to cope with quarantine countermeasures and restrictions [36] with the help of open spaces for recreation, sports, etc., and with easy non-vehicle access. To implement this, it is suggested that the ideas of a complete neighbourhood and 15-minute city, which recommend lively and repetitive decentralized proxemics, be applied in the design of cities [37], [38]. This idea is also in line with the goals of sustainable development for public access to public green spaces [39].

2. Improvement of Walkways: Increasing the Width

Walkways should be more extensive and should be consistent with new behaviours. The following suggestions are provided in this regard:

i. Widening of Walkways

By increasing the width, it is possible to observe more and better physical distancing of pedestrians. In this way, a suitable context with the potential to maintain and promote this means of moving in the future of cities is provided [40].

ii. Spiral Design of Walkways

Spiral and one-way path (especially recreational): One of the ideas presented to maintain distancing by the Pretch office is to design a park with spiral and one-way paths with a width of 240 cm and ridges separating passages with a width of 90 cm. These routes have entrances and exits, and are designed to take 20 minutes to complete from the beginning to the end, so there is no need to stop along the route and crowd up. With this designing method, people who are walking are prevented from facing and standing next to each other, and social distancing is applied to control the disease transmission [41].

3. Making the Medical and Health Care Services Possible in Open Recreational Spaces

Parks may have been crucial in the way people handled the effects of the COVID-19 pandemic, particularly the increasingly limited recreational opportunities, widespread financial uncertainty, and consequent heightened anxiety [42]. The use of this type of space as a temporary treatment and care centre at the peak of the epidemic and thus its role in crisis management has been noteworthy. Therefore, in designing the body of this urban space, designers must pay attention to wide, flexible, and receptive spaces of temporary structures. This is especially important in public spaces and large parks in city centres and adjacent to hospitals, which are used not by the neighbourhood, but also by the whole city. During the COVID-19 peak period, this happened in the courtyards and garages of many hospitals, including the Mississippi Hospital [43].

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4. Upgrading Transport Hubs[1] to Combined Terminals with Quarantine Facilities

Every day, a large number of passengers travel between transportation hubs. This indicates the high chance of these hubs spreading viruses and diseases [44]. Because travel restrictions and barrenness of these spaces are not permanent, it is recommended that the design requirements of these urban spaces be updated and combined with new behaviours, based on solutions such as the consideration of areas and units for rapid detection, quarantine places, and automatic disinfection system.

5. Improving Mobile and Decentralized Urban Services such as Mobile Gas Stations and ATMs

Due to transport restrictions in post-COVID-19 life, services that were stationary and needed to be referred to should be mobile and decentralized today. Development of this service method in cases such as mobile gas stations, mobile ATMs, food preparation and delivery centres, and mobile testing and care centres [45] are very effective in preventing outbreaks, especially in low-income and developing areas. In addition to the mentioned advantage, the reduction of urban traffic and the pollution caused by it is an extra benefit that will cause their stability, continuation, and economic justification in the long run.

6. Improvement of Urban Signs and Street Screens

Informing through urban elements such as digital screens on city walls and highway signs is one of the characteristics of urban management that can play an effective role in controlling the virus spread by subconsciously reminding citizens of the necessities of the pandemic. It is suggested that in addition to the use of screens, signs dedicated to health issues be designed and implemented, especially during pandemics.

7. Considering and Developing Urban Car-Based Areas

Many COVID-19 vaccination centres provide services in the parking lot or on the premises and in clients' cars. Thus, people unfamiliar with the high risk of disease transmission did not need to attend common spaces. In addition to controlling the spread, this helped control the fear and psychological distress. This type of attendance was used more and more in many chain restaurants. It seems that attendance with a car can be a good alternative, and the requirement for this is the flexible designing of spaces to enable people to attend with a car while observing the relevant standards .This concept was also used for watching movies outdoors as drive-in movies/theatres in 1933. In this way, the passengers of the cars would sit and watch the movie or theatre from inside their car when the car entered the show space, with the standard distancing [46].

C. Architecture

1. Reevaluation of Residential Interior Design Based on Resident's New Behaviours

Today, activities such as education, work, exercise, etc., have been added to the living space to some extent. Therefore, it is necessary to apply new considerations in housing design. For this purpose, the design of interior spaces with open and flexible plans for multi-purpose use and conversion into temporary private spaces (during working time) is recommended. In open plans with mobile walls and partitions, comfortable and private spaces can be created for parents and children to study and work [47]. In addition, considering this method of design, living rooms that are flexible, can change and move, and have become a necessity are included in housing design. Through this, houses will also have spaces for children to play and exercise [48], [49].

2. Reconsideration of Design in Entrance Space Design

With the emergence of a new level of hygiene in daily life, entering the home space comes with tasks such as washing hands, changing or disinfecting clothes and shoes, etc. Under such circumstances, the entrance space architecture, especially in the residential spaces, acts as a separator to filter outside (unfamiliar people with more transmission danger) and inside (familiar people with lesser transmission danger). This way, it helps people operate with less connection to the interior. In addition, in multi-story buildings, it is necessary to design in such a way that the contact of people with each other is minimized and movement from the entrance to the apartment or unit occurs with minimal contact [50], [51].

3. Designing the Building's Facades as an Architectural and Urban Mediator Space for Social Interactions

With social distancing, the attendance of human beings in public spaces (which plays an essential role in the quality of life, especially the psyche of individuals) has been weakened. During the pandemic, the attendance in public spaces in many cities and neighbourhoods has been replaced by the presence on balconies and terraces of buildings, especially residential buildings. Therefore, these architectural spaces should be considered more than before to play a major role in restoring welfare and social interaction. It is suggested that the balconies be arranged in such a way that while abiding by the laws of the proximity of buildings, shared space is used to create a close collective activity. The facades of the building should be designed as a mediator between indoor and outdoor privacy to play the role of public-private space with the ability to maintain physical privacy and urban vitality [52], [53].

4. Valuing the Importance of Semi-Open Green Spaces in Architecture

As mentioned before, one of the positive consequences of the pandemic was paying attention to nature to get rid of the isolation and use its healing effects [54]. Due to the unbalanced distribution of parks and urban gardens in the city and the lack of easy access, nature can be included in architecture (especially housing) or the possibility of watching nature and the open environment can be increased [55]. Therefore, increasing the importance of balconies, courtyards, and roofs – in which the

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[1] A transport hub (also transport interchange) is a place where passengers and cargo are exchanged between vehicles and/or between transport modes.

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use of fresh air, the chance to see natural perspectives, and the sense of presence in nature is strengthened by planting – is one of the requirements for designing buildings (especially in residential spaces) in post COVID-19.

5. Reevaluating Air Conditioning System

Ventilation and air conditioning have become more important in buildings, especially where there is a different occupancy rate of people who do not belong to the same family [56]. Because opening the windows causes a waste of energy, it is necessary to apply changes in mechanical ventilation and air conditioning systems such as increasing fresh air intake, increasing negative pressure, system disinfection cycles, etc. [57].

6. Promoting the Importance of Flexibility and Variability in Architecture

Flexibility is an approach to adapt the design to changing needs [58], and in the pandemic, public buildings with this feature and the ability to modify the form and use were successful. This feature was especially used for crisis management and office spaces, such as the idea of changing the Berlin's Brandenburg airport into a COVID-19 'super-hospital' proposed by Opposite Office in Germany [59]. In addition, due to mobile architectural elements, many workspaces were able to create a safe space by changing the dividers and layout according to the new requirements [60]. Therefore, in post-COVID architecture, the architectural elements should be considered as flexible as possible.

7. Development of Lightweight Architecture

The use of mobile, lightweight, and modular elements is a requirement of flexible architecture.

Lightweight and mobile ceilings and mobile walls are recommended for use in spaces such as closed concert halls and amphitheatres, as well as office and residential uses. For example, according to the required needs in the workplace, spatial changes can be made through walls that can change dimensions with modular and lightweight parts.

8. Promoting Transparency in Architectural Design

Today, the separation and isolation of space is one of the architectural requirements, especially in the design of the workspaces. Due to the multi-sensory nature of the architecture and the need to maintain the visual connection and the brightness of the space, these actions should be done with transparent separating materials such as glass and transparent nano structures [61].

D. Space[2]

1. Crowd Control and Securing Elevators

Elevators with a closed and limited space have a high risk of transmitting the virus. This risk is higher in public buildings for two reasons: the greater number of users and the fact that users are not from the same group or family.

Securing this space through the presence of doormen, the use of visual and weight sensors for crowd management [62], and the increase in the number of elevators with a smaller area instead of fewer elevators with a larger area (to reduce the risk of stranger contacts) can be achieved. Avoiding virus transmission from surfaces can be attained through object design suggestions in the next section.

2. Making Visual Privacy in Space

Creating visual privacy by drawing a line on the ground was a common method of crowd management in the Corona pandemic. This requirement is also suggested through smart flooring, weight sensors, and the use of light and colour. In addition, floorboards with signs and inscriptions in spaces such as the waiting area before the elevator, ATMs, office counters, pharmacies, etc., are suitable ways to create spatial privacy.

3. Designing Disinfectant Spaces and Compartments as a Filter

Since the level of hygiene required for different uses is variable, it is suggested that spaces called 'clean zone filter' are designed and implemented to provide a certain level of hygiene before entering. Examples of this space include a dust-washing sink and UV sterilization designed in South Korea to use before entering a children's play area [63].

4. Touch-Free Lavatories

Touch-free lavatory as a space where passengers can activate the waste flap, faucet, toilet cover, soap dispenser, and even the door lock just by waving hands reduces the fear of virus transmission from the surfaces. This concept is implemented in China and is recommended for public spaces, especially on airplanes and trains [63].

E. Object

1. Designing Mask Holders

By turning the mask into one of the essential and accompanying accessories for people, it is necessary to consider mask holders in the form of straps (such as straps of glasses) or hangers in the design of objects. Hanger pedestals can be installed at homes, in personal cars, in restaurants, and wherever masks are removed [64].

2. Equipping Meeting Rooms and Educational Spaces with Microphones

The use of facemasks and mouth covers reduces the auditory perception of individuals, so in meeting rooms where there is a need to increase the distance, it is recommended to use microphones.

3. Designing Disinfection Stands

Due to the need to disinfect hands, shoes, and clothes before entering, it is recommended that disinfection stands equipped with electronic eyes or pedals (sanitizing gates), showers, and disinfection cabinets be designed and installed in the space, especially entrances.

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[2] The location of objects; examples include children's play space indoors, sitting area of beauty salon units, and the space of the devices of gyms.

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4. Applying Shoe Cover Stands

Shoe covers are the best way to prevent the transfer of outdoor pollution into buildings, especially non-residential ones. Due to the possibility of the contamination of hands, while covering, it is better to do this by the automatic boxes, which cover the shoes by placing the feet on them.

5. Applying Physician Assistant Robots

The design of robots in the treatment and health care sector can minimize the exposure of nurses and hospital staff to patients. For example, a robot called Moxi was designed at Texas University with programmability and remote control and has been used in Dallas health centres [65].

6. Anti-Virus Materials

By designing anti-virus materials, surfaces that are considered to be at risk of transmitting the virus are secured without the need for disinfection. "Virutect" is a response to COVID-19 or other viruses that are adhering to tables, walls, doors, and so on. This Japanese textile material can be used with a variety of options including HPL laminates, non-combustible wall panels, counters, toilet cubicles, and interior doors [63].

7. Developing Usage of Virus Detectors

Checking people's body temperature before entering public buildings has been a common control method, but it is mostly done by security guards or lobby men. In this regard, the design of more accurate diagnostic devices can be useful in keeping buildings safe from outbreaks. Examples include the 'Spindiag Rhonda' system, which detects the virus in 40 minutes, and MIT's artificial intelligence models, which can tell the difference between coughing in healthy and infected people [63].

8. Designing Face Cover and Shields

Over the past two years, various types of facemasks and shields have been designed, produced, and distributed in the market. In addition to the use of technology and helping health care, this has also entered the field of fashion and design. Many facemasks with virus detection technology have helped promote health and well-being through the kits that are placed inside them [66].

9. Repositioning the Control Keys

To minimize touching the objects, it is necessary to move the entry and exit handles, elevator keys, or power switches from the current height (about one meter and more) to a height close to the floor. In addition, by changing the dimensions and shape, it must have the ability to be pressed with the foot. This is especially recommended when it is not possible to replace the key with the electronic eye.

10. Replacing Handles with Pedals

To minimize touch, the use of electronic eyes should be expanded as much as possible in the design of objects such as doors and windows. In cases where there are limitations in this area, it is recommended to turn the handle to the pedal.

11. Designing Furniture Equipped with Compartments and Dividers

It is not always possible to create safe physical distances between furniture due to space limitations. Therefore, it is better to create safety through shields and compartments in furniture. In the design of the project called 'Shield', designed by Iusepp Ianzillo and Iuseppe Gurrado, glass dividers or plexiglass are placed on the furniture in line with the consideration of the aesthetics and harmony with the surrounding environment [67]. In this way, the pre-pandemic furniture can be used without any fundamental change after the pandemic. Another example of designing a furniture separator happened in one of the restaurants in Tokyo, Japan, where each guest was placed under a compartment of transparent material in the shape of a lantern to feel more comfortable when removing the mask [67].

12. Designing Furniture Based on New Standards

By increasing the privacy of people and considering that it is not possible to use separators and compartments in all places, in some spaces such as waiting rooms, distances and privacy can be applied through furniture design. To this end, the width of the support should be more than 60 cm and according to the required space. For example, NGHOI design studio conceptualizes the "Chill Out Chair" with an open heart and open arms [68].

IV. CONCLUSION

Statistically, the possibility of pandemics is increasing and humanity is facing the threat of infectious diseases more than ever. Different areas of human life need to be prepared to confront crises arising from this threat. In this regard, we first studied the ramifications of pandemics from the past to the present in eight realms of human life. Then, we examined the solutions and paradigm shifts formed in the spatial fields in response to the issues created after the outbreaks and observed the similarities in the formed spatial practices. This way, we concluded that the changes in the way of using the space could lead to controlling the harmful effects of the pandemic in different realms and thus be effective in preventing future outbreaks. Therefore, the corrective design instructions that would adapt the space to the conditions caused by the outbreak and the conditions after it and would prevent the rapid spread and the formation of a pandemic (and as a result reduce the troubles in the future) were finally presented in order to be applied by the designers and users of the space.

Every study is limited in some way, and this study is not an exception in this regard. The study at hand faced two major limitations. First, the data were collected in this research project through the archival studies method rather than experimental methods. That is to say, by observing the solutions emerged in response to the conditions caused by the pandemic, the next steps of the research were formed. In addition, despite the fact that the pandemics have been repeated many times, no coherent spatial responses have been prepared for them so far; hence, the guidelines presented in this research are superficial. It is necessary to get the long-term feedback of the users on the applied instructions and evaluate them more deeply through future survey experiments. Moreover, despite the similarity of

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spatial practices in response to post-pandemic issues, the guidelines should be reviewed and updated in due course due to the diversity of diseases and the impossibility of the full prediction of pandemics in the future.

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