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ARTICLE

Assessing the Role of Environmental Factors in the Transmission of Infectious Diseases in Communal Spaces

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ABSTRACT

Communal spaces provide different facilities for users while they are the primary place for the spread of diseases, especially respiratory. Transmission is possible through human behaviors, the way they communicate with each other and breathe in an environment by airborne pathogenic particles. Experts from various fields have gained valuable experience and achievements regarding how to prevent these diseases by means of environmental factors. Due to the spread of the corona virus in the past years, environmental planners and designers seriously considered the need to review the design and use of spatial components. This study provides a framework for decision making and design of communal spaces based on how environmental components can be effective in preventing the spread of respiratory diseases such as coronavirus and influenza. The research method used in this article is logical reasoning combined with ANP method and focus group discussion. According to the results of this research, indoor air quality plays the most crucial role in preventing the transmission of viruses (contagious respiratory diseases) based on expert groups.

Keywords: Well building; Healthy building; Contagious diseases respiratory; Air borne transmission

1. Introduction

As humans, we live in space and are surrounded by, both public and private. There is no escape from it. In times of need, we can only change the living space and go from place to place. Quarantine is usually the last place we live and if we get infected. The reason is clear; the place where the least use

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and traffic takes place and important protocols are implemented. Research has often forgotten the factor of the space in which man lives and is closer to it. The amount of space usage and connection with its components in various spaces is different. As an intelligent component with special features, the virus exists everywhere. How people encounter space on the one hand, and the effect that space and its components such as surface, dimensions, material, etc. have on the virus, all play a decisive role in the spread of the virus among humans.

The topic of occupant health in public buildings is an emerging area for both academic research and industry practices. The World Health Organization (WHO) defines health as "a state of complete physical, mental and social well-being" [1]. Physical well-being is defined as the appropriate functioning of our bodies and our ability to resist illness. Mental well-being includes more than merely the absence of mental illness; it is comprised of mental resilience, contentment, confidence, and peace of mind. Finally, social well-being is the ability to build meaningful relationships with others; it is determined by an individual's sense of belonging, and social engagement [2]. One of the threats that societies face today is the spread of infectious diseases in communal spaces. There are several ways of transmitting respiratory pathogens. Spread or transmission can be through close contact with humans or by human touch [2,3]. The most common way of spreading respiratory infectious diseases is through respiratory droplets when an infected person coughs or sneezes. These tiny droplets can infect a healthy person by sitting on the face (mouth, nose, ears, and eyes) or hands [4]. Contagious diseases respiratory can remain on different surfaces for a long time, which is one of the important reasons for the transmission [2].

1.1 Airborne transmission

The use of Disinfectants decimates microorganisms of viruses or bacteria on internal layers or inert surfaces by acting as an antimicrobial mechanism. Disinfectants are not always impressive against all kinds of microorganisms like bacterial spores as sterilization, which kills all types of life by the use of extreme physical or chemical procedures [5]. Many researches have been conducted on the effect of environmental factors and the form of spaces on the airborne transmission of disease particles, mostly due to the importance and epidemic of SARS virus (COVID) in the study of this virus. Many indoor spaces have a high occupant density, but do not provide adequate fresh air [6], which increases the infection risk through airborne transmission. The transmission by airborne route was considered to greatly contribute to some reported outbreak events. For example, the SARS-CoV-2 spread among the members of the Skagit Valley Chorale during a weekly rehearsal eventually making 53 out of 61 members infected. Such a severe spread was highly suspected to be caused by the airborne transmission [7]. The outbreak event that happened in a Guangzhou restaurant was likely caused by recirculated air, which carried infectious aerosols emitted by an index case [8,9]. A retrospective analysis of these two outbreak events also supported the airborne transmission of SARS-CoV-2 [10]. The outbreaks in a tour coach in Hunan province [11], a communal space in Seoul [12] and a tour coach in Zhejiang province [13] also indicated the possibility of airborne transmission. It is increasingly clear and accepted that airborne transmission is an important contributor to the rapid and long-distance spreading of SARS-CoV-2 [14]. Indoor air quality (IAQ) control strategies can be applied to reduce the infection risk of COVID-19 through airborne transmission [15,16]. Improving indoor ventilation systems, using air cleaning technologies, and wearing masks can enhance the IAQ and decrease the infection risk immensely. These strategies have been introduced and discussed in other published papers [17,18] and recommended by WHO [19], U.S. CDC [20,21] and ASHRAE [22]. A well-known mathematical model for estimating the infection risk through airborne transmission is the Wells-Riley model [23,24]. It assumes well-mixed air and a steady-state infectious particle concentration in a confined space.

1.2 Temperature & light

Various research has been done in the field of

different environmental conditions and their relationship with the transmission of viruses and respiratory pathogens. In this context, these studies can be mentioned: In a study, the persistence of SARS-CoV-2 in environmental conditions was measured at different temperatures. The virus is very stable at 4 °C, but sensitive to heat at 4 degrees Celsius, only approx. 0.7 infectious reduction logging units Title on day 14. With an increase in the temperature to 70 degrees Celsius, the virus deactivation time is reduced to 5 minutes [25]. The microbe that causes tuberculosis, Mycobacterium Tuberculosis is called tuberculosis, which affects the lungs in most cases it makes, but it can influence other parts of the body as well. Tuberculosis bacillus is very sensitive to sunlight as a result good and dark places become more and more. In general, TB is a socio-economic disease and everywhere there is a population that gathers a lot under one roof and has proper nutrition and hygiene not to worry and live in poverty, they are seen more often. Housing situation plays a significant role in people's illness, houses are dark, and unsanitary grounds for choosing their inhabitants prepared for tuberculosis [26].

1.3 Surfaces

A comparative study of SARS-CoV-2 and SARS-CoV-1 viruses is done and a comparative study of both viruses shows that SARS-CoV-2 and SARS-CoV-1 have significant sustaining time on different surfaces. This research showed that the persistence of the virus on the surface is directly related to their gender. In this way, the longest shelf life is related to plastic with 72 hours, then steel with 48 hours shelf life, and the lowest copper with 2 hours shelf life [27]. Due to the fact that infectious respiratory diseases are transmitted through the transmission of pathogens in the air between sick and healthy people, studies on the airborne transmission of viruses are discussed. In seminal papers from 1930, Wells proposed the concept of droplets and droplet nuclei that has dominated thinking about airborne infection over the ensuing decades. Wells commented that larger droplets, governed by Stokes' law, would fall quickly to the ground, while smaller droplet nuclei, formed from droplets that evaporated and left behind solid residue, would stay airborne for longer periods of time. Since then, studies in the field of aerosol science have shown that exhalation and various exhalatory activities, e.g. singing, variably generate thousands of small par-tickles (of multiple size modes) that can travel well beyond 6 feet and accumulate in poorly ventilated indoor spaces [28].

From the review of previous studies on the effective components in the transmission of airborne infectious diseases, three important factors and indicators are extracted (**Figure 1**).

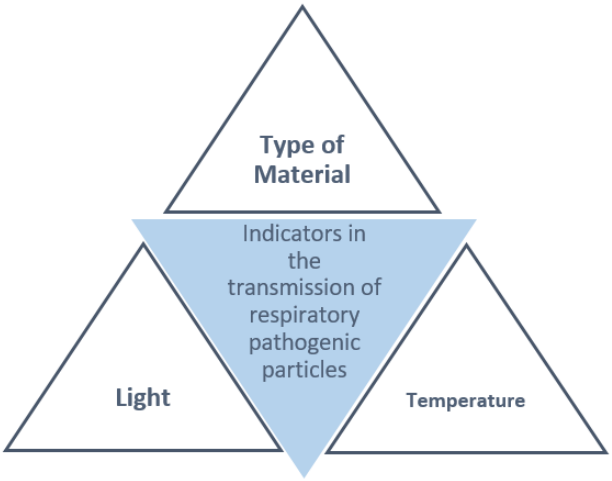

Figure 1. Primarily clustering of important indicators in the transmission of respiratory pathogens from previous studies.

1.4 Well building

Due to the fact that a healthy building is a subset of a good building, the well standard model is used to provide other indicators of a healthy building. These components can play a role in the transmission of airborne particles of infectious respiratory diseases.

WELL Building Standard: Delos Living LLC is an American-based organization that says its mission is 'to build a better world'. It suggests that it transforms the indoor environment by placing health and 'wellness' at the center of design and construction decisions through research, consulting, and real estate development, and by offering innovative solutions for the built environment. The standard is based on seven years of research in partnership with scientists, doctors, and architects exploring the connection

between the buildings where people spend their time, and the health and well-being impact those buildings have on their occupants. It is third-party certified by Green Business Certification Inc. (GBCI), which administers the Leadership in Energy and Environmental Design (LEED) program (Delos Living LLC, 2020) [29].

According to the WELL building standard (**Figure 2**), the following components are defined and Spaces can become WELL certified by achieving a defined score in each of seven categories:

Figure 2. Well Building Standard V2—Concepts and Features, Delos Living LLC [29].

The project can pursue no more than 12 points per concept and no more than 100 points across the ten concepts. 10 additional points are available in the innovation concept (innovative credits).

1.5 Healthy buildings

The term "healthy buildings" is emerging in the literature; researchers have previously focused on "sick buildings," or the "Sick Building Syndrome" (SBS) to address "Building Related Illness" (BRI) [30]. Clearly, the idea of designing places to support resident health has only been recently adopted. A "healthy building" is defined as a built structure that promotes the positive well-being of individuals [31].

Considering that a healthy building is considered a subset of a good building, the components of a healthy building will be presented in order to finally reveal the effective indicators in the airborne transmission of respiratory disease particles. Despite the importance of healthy buildings, rather than avoiding sick buildings, we do not have a clear and commonly accepted definition of what "healthy building" means to building professionals and occupants (**Figure 3**). Moreover, designers do not have a routine process to integrate the fundamental definitions of health offered by the WHO, as explained earlier, in buildings.

A healthy building may be better defined as a building, including all of its systems, that promotes and sustains the health of its occupants, as a state of complete physical, mental and social well-being. As a result of emerging environmental concerns (e.g., climate change, pollution), demographic shifts (e.g., aging population), lifestyle changes (e.g., global epidemics of stress, longer working hours), the role of building professionals and researchers in healthy buildings will be highlighted. It can be said that the components obtained from previous research, the indicators of good building and the components of the healthy building, each play a role in the transmission of airborne particles of respiratory diseases from different dimensions.

According to what has been stated, the question of this research is: What criteria should be considered to increase the communal space resilience against contagious diseases respiratory? How can a process facilitate the selection of criteria be proposed by forming a discussion group with the experts' choice?

The premise of this research is that using both FGD① and analytical network process among the spatial indicators of architecture in the transmission of infectious respiratory diseases, he identified the most important factors in order. Many researches have been conducted in the field of infectious diseases in various fields of medicine, environmental health, environmental design, architecture and urban planning, and there is a lot of accumulated knowledge

① Focus Group Discussion

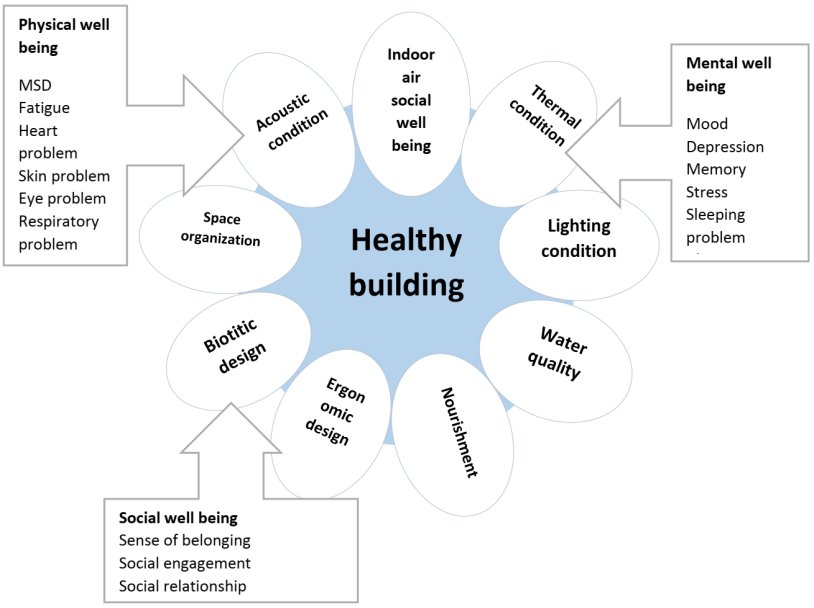

Figure 3. Air quality and healthy buildings concept [32].

related to this issue. Based on this and according to the purpose of the research, which found the spatial component as one of the most effective agents in the transmission of airborne particles of infectious diseases, the conceptual process model of the research is presented (**Figure 4**).

2. Materials and methods

The research method used in this article is logical reasoning combined with ANP② method and focus group discussion. This is a practical method when desiring to solve real-world issues [33]. The analysis of indicators and their prioritization has been done by Mat-Lab program. The method of data collection is field and library and the research tool is the analytical network process. According to the scope of calculations and accuracy in the computational process, the Mat-Lab program is used to form the process and perform calculations. This study has two main phases so that collect and weigh qualitative criteria to help explain and build upon the quantitative results. The study encompassed a quantitative component (analytical network process) and a qualitative component (focus group discussions). ANP method is used in various fields of science, including engineering, management, business and science; to help decision makers make good choices [34]. The purposes of using such methods are evaluating, choosing, ranking and sorting alternatives. FGD is a way of gathering data that involves engaging a small group of (expert) people 'focused' on a particular topic or set of issues [35]. Also the group consists of two doctors, two environmental health experts, two urban planners, two architects, and two environment designers who had experience working in communal spaces of Hamedan city and dealing with coronavirus patients. The most significant applications of the discussion group method are: 1) Obtaining an information background with existing and potential characteristics of individuals and groups in areas related to the goal. 2) In-depth discovery and search and expertise concerning the general needs of groups as well as information are hidden in the thoughts and ideas of the people. 3) Estimating opinions in thought combinations are related to how to achieve social needs [36].

Considering that the members of the group are all residents of Hamadan province, so, their observations of the type and extent of the spread of infectious diseases, including the coronavirus, in this city will have an impact on the results of this study.

The analytical network process begins with identifying and prioritizing decision elements. These

② analytical network process

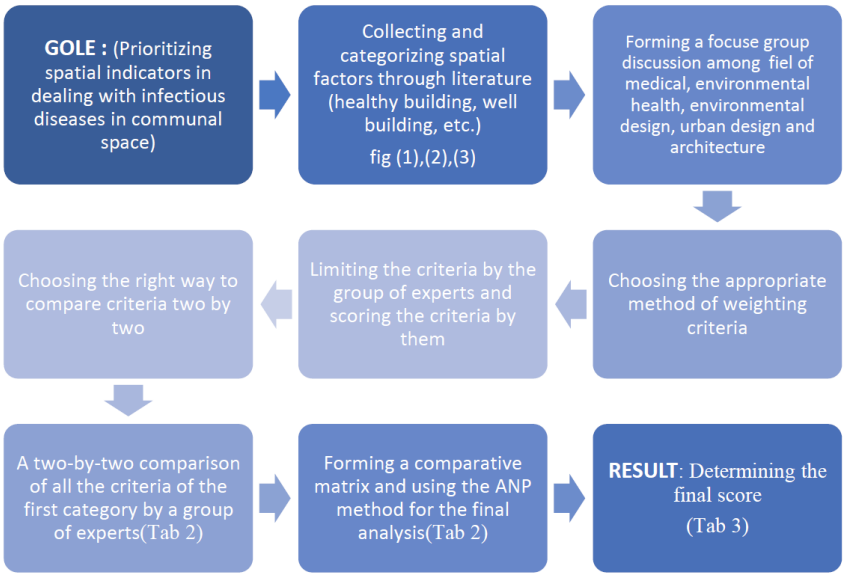

Figure 4. Study design process.

elements include goals, criteria, characteristics and possible options used in prioritization. The existence of structure is because the elements of decision-making (options and decision-making criteria) can be summarized at different levels (**Table 1**).

Table 1. Degree of preference in ANP [37].

Score (degree of preference)	Description	Explanation
1	Equal importance	Two criteria are equally important
3	Slightly more important	Two criteria are equally important
5	more important	Experience shows that i is more important than j
7	Much more important	Experience shows that the importance of i is much more than j
9	Absolute importance	Absolutely is more important than j
2, 4, 6, 8	Intermediate preferences	

3. Case study

In the study of the statistics of infection and deaths caused by corona disease in Hamedan province, from the beginning of the epidemic of this virus to May 2, 2021, about 37,812 people were infected with coronavirus in Hamedan province, and among them, 15,330 patients were hospitalized, and this number was 5,618 in Hamedan city for whom that has been infected with this virus and hospitalized. The number of deaths from the coronavirus in the province has reached 1,951 people since the beginning of the outbreak until the mentioned date [38], which shows the importance of managing and re-examining the strategies for dealing with it, including spatial factors affecting its spread.

4. Findings and discussion

This finding clarifies that each of the spatial indicators has a role in the spread of viruses and their transmission from the perspective of experts in various fields of medicine, environmental health, environment design and architecture. The indicators were gathered in the literature section and downsized by focus group discussion. They prioritized the ANP method by experts in fields related to the purpose of the research (**Table 3**). Each of these factors has a determining effect on the probability of infectious and respiratory pathogenic particle transmission. Their combination with other spatial indicators in the context of space along with factors such as the use of space has a significant effect on the probability of translocation (**Table 2**).

Table 2. Related criteria and sub-criteria, on an example of Matrix of two-by-two weight comparison of criteria derived from the average weighing by experts, authors.

Numb	Criteria	Explicate
1	Spatial use	Permanent, temporary
2	The user of space	All habitant, children, adults, …
3	Spatial dimension	Space length, Space width, Space height
4	Depth of space	away from the original space, Main and secondary space
5	Spatial distance	The distance between center of space
6	Spatial community	Public transport, private transport, social activity…
7	Type of surface material	Antibacterial and antiviral materials, Using metals such as silver, brass, zinc, copper, Stones such as marble, travertine, turquoise, azure, etc. Not using steel, plastic, etc. brick, Stone, ceramic, Floor Covering, Parquet, Mosaic, Antibacterial and antiviral materials
8	Air quality	Natural ventilation, Fan, air conditioner, Ventilator
9	Space lighting	Direct sunlight, Direct Southern sunlight, Direct Eastern sunlight , Western front, Northern front
10	Space coloring	Red and dark on the floor, Red and dark on the wall
11	Vertical communication	Elevator, Residential and commercial complex
12	Construction technologies	Floor heating, air conditioning, Air curtain system, X virus, Automatic doors, Positive Air Pressure system
13	Crowding	Face to face, social distance,
14	circulation	Air flow, windows, handle and automatic door
15	Space temp	Natural sunlight, type of heating and cooling devices, air conditioning

Table 2 continued

Criteria		1 Spatial use	2 The user of space	3 Spatial dimension	4 Depth of space	5 Spatial distance	6 Spatial communication	7 Type of surface materials	8 Air quality	9 space lighting	10 Space coloring	11 Vertical communication	12 Construction technologies	13 Crowding	14 circulation	15 Space temp
1	Spatial use	1	1/3	1/3	1/3	1	1/5	3	1/5	3	7	3	1/3	1/5	1/3	1/3
2	The user of space	3	1	3	1/3	1	1/3	7	1/5	3	9	5	1	1/7	3	1/5
3	Spatial dimension	3	1/3	1	3	3	1/3	3	1/5	5	9	7	3	1/3	5	1/3
4	Depth of space	3	3	1/3	1	3	1/3	3	1/3	5	9	7	3	1/3	3	1/3
5	Spatial distance	1	1	1/3	1/3	1	1/3	3	3	3	7	5	3	1	1/3	1
6	Spatial communication	5	3	3	3	3	1	5	1	3	7	5	3	1	3	3
7	Type of surface material	1/3	1/7	1/3	1/3	1/3	1/5	1	1/5	1/3	3	1/3	1/5	1/7	1/5	1//3
8	Air quality	5	5	5	3	1/3	1	5	1	5	7	5	5	3	5	9
9	space lighting	1/3	1/3	1/5	1/5	1/3	1/3	3	1/5	1	3	3	1	1/5	1/3	3
10	Space coloring	1/7	1/9	1/9	1/9	1/7	1/7	1	1/7	1/3	1	1	1/3	1/5	1/3	1
11	Vertical communication	1/3	1/5	1/7	1/7	1/5	1/5	3	1/5	1/3	1	1	1/3	1/5	1/3	1/3
12	Construction technologies	3	1	1/3	1/3	1/3	1/3	5	1/5	1	3	3	1	1/3	3	3
13	Crowding	5	7	3	3	1	1	7	1/3	5	5	5	3	1	5	3
14	circulation	3	1/3	1/5	1/3	3	1/3	5	1/5	3	3	3	1/3	1/5	1	1
15	Space temp	3	5	3	3	1	1/3	3	1/9	1/3	1	3	1/3	1/3	1	1

Matrix of two-by-two weight comparison

Each space has its unique features such as length and width, height, depth of ambient and natural light, the amount of ventilation, the surface material, and most importantly, its use and the amount of its use the level and lifespan of the virus vary on different surfaces and colors. Natural light, fresh air, the material of the surfaces, each has different effects on the persistence of the virus and the possibility of its transmission. These cases may have been unimportant and unnecessary for people before. Today, most health recommendations consider one or more of these factors and how people deal with them. In general, these indicators can be presented and weighted at the same time using the series analysis method (**Table 2**).

Depending on their character, application, physical characteristics, such as the type of surfaces, the amount of equipment used, and the transition that takes place, spaces can prevent the transmission of the virus or increase its transmission rate exponentially. It is the shared living space that includes people, which has a huge impact on the behavior of the Infectious and respiratory pathogenic particles (virus), their durability, how it moves, and ultimately the possibility of transmitting to another person. The total score is calculated by MATLAB software by comparing the indicators with each other, which was previously determined by FGD. Therefore, the quantitative values of the impact and final score of the spatial indicators have been obtained according to the process mentioned in **Figure 4** in **Table 3**.

Given the fact from **Table 3**, based on the purpose, spatial ventilation is ranked first. The next is awarded to the spatial communication, crowding, spatial dimension, space temp, depth of space, the use of space, spatial distance and type of surface material, respectively.

The strength of this study is the use of the opinions of experts in different fields and its analysis by MATLAB software. By bringing this different expertise together, more effective solutions can be provided because each of them looks at the issue from their own point of view and the sum of these views is more than their individual opinions. One of the most important limitations of this article was the lack of statistical information, especially location-based statistics regarding the effective factors in the spread of infectious diseases in communal spaces.

Table 3. Ranking of criteria based on the effect on Infectious and respiratory pathogenic particle transmission, authors.

Importance	Criteria	Final score
1	Air quality	0.215
2	Spatial communication	0.154
3	Crowding	0.142
4	Spatial dimension	0.129
5	Space temp	0.112
6	Depth of space	0.111
7	The user of space	0.089
8	Spatial use	0.057
9	Spatial distance	0.042
10	Direct natural lighting	0
10	Space coloring	0
10	Vertical communication	0
10	Construction technologies	0
10	Circulation	0
10	Type of surface material	0

5. Conclusions

Nowadays, the issue of infectious diseases has become one of the principal problems in societies, in such a way that with every pandemic, many social activities in communal spaces face problems, and many people in these spaces get infected with those diseases. The World Health Organization (WHO) defines health as “a state of complete physical, mental and social well-being”. This study tries to determine the indicators related to physical and social areas and examine the effect of each of them on preventing the spread of infectious diseases and as a result achieving a healthy building. The surrounding environment in communal spaces has many capacities, and the right decision about the use and changing them can help in the face of infectious diseases. In other words, different fields of knowledge have different views on environmental capacities, and taking advantage of the personal experiences of specialists

in separate scientific fields can be an optimal way to deal with these conditions. The results of this research are based on the quantitative method and using both FGD and analytical network processes. In this study, spatial criteria extracted from the literature review were evaluated and finally, the most important ones were selected by experts, those who somehow had the experience of dealing with infectious diseases, including the coronavirus, in Hamadan city. According to this process, the degree of importance and significant difference of the results shows that the factor of air quality can have a very high effect. The "Air Quality" in communal spaces is the main criterion for the transmission of pathogenic respiratory particles (**Table 3**). This method can play an important role in finding the most effective factors in the environment of the public building by considering the effect of all criteria in the analytical network process. This process will play an effective role in making decisions and designing communal spaces that can deal with the spread of airborne particles of infectious diseases. According to the logical reasoning approach of this research, although the group of experts has determined and weighted the indicators based on their experiences in Hamadan city, the results of this study can be generalized to other cities as well. As a result, due to the high efficiency and relatively low costs of taking advantage of clean air, such as using natural air by leaving openings or filtration, it is possible to reduce the amount of transmission of diseases through airborne particles.

Authors Contributions

This research was done collaboratively by all the authors listed on the first page.

Conflict of Interest

There is no conflict of interest.

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