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Adaptive Design of the Built Environment to Mitigate the Transmission Risk of COVID-19

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Abstract The recent global outbreak of highly contagious novel coronavirus disease has aroused public concern on environmental health and personal hygiene issues. The world has seen the rapid spread of transmission of this infectious disease within the built environment as well as outside. Each country is facing a tremendous challenge to get rid of this disease. Addressing this global concern, the primary objective of this paper is to instigate a discourse about the potential contribution of adaptive design of the built environment on public health specially in residential sector of Bangladesh. Also, this paper assesses a framework which will provide a guideline responding to pressing questions about future considerations labeled as 'The new normal' and it will be helpful for other scenarios as well. Methodologically this discussion is based on a framework, which is utilized for the analysis of existing current situation and is operationalized by identifying and mentioning design implications. Moreover, this paper originates insights for areas where future research will be critically needed through discussing some key issues. Finally, the paper concludes with an outlook that captures considerations regarding practice of public health in adaptive use of the surrounding built environment to mitigate the transmission risk of COVID-19.

Keywords: *COVID-19, adaptive design, pandemic control, built environment, hygienic solution, transmission risk mitigation*

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1. Introduction

The usual pace of human life has suddenly come to a halt guiding no direction, thanks to an invisible organism. A novel form of coronavirus (SARS-CoV-2), which is highly contagious and responsible for the coronavirus disease (COVID-19) has generated a global public health crisis. It has completely changed people's lives in just a few months. People are facing new challenges day by day because of this COVID-19 crisis. The rapid spread of COVID-19 has brought increased attention and concern regarding the control and prevention of SARS-CoV-2 from every class of people. It is being addressed at various local and global scales through various measures & guidelines including social distancing. These types of measures are associated with debates about the nature of our living and working patterns, mostly about the built environment surrounding us.

The COVID-19 disease has already known as pandemic. Since the previous decades, many contagious diseases have been turned into pandemic and space has played an important role in all these cases. Previous contagious diseases such as SARS, MERS, Ebola, Bird flu, Swine flu, Influenza A(H1N1pdm09) etc. have a significant impact on spaces as well as built environment. Each pandemic has changed the concept of lifestyle and built environment by evolving new aspects. Also, lifestyle and built environments are proved helpful in case of their involvement with controlling the spread of infectious diseases. This research with the known information about SARS-CoV-2 will try to provide achievable and actionable guidance to the built environment decision makers and all indoor occupants attempting to minimize the transmission of this infectious disease. People can reach to the solution of the transmission risk mitigation to a great extent by maintaining these guided acts and strategies based on adaptive design of the built form. With the help of some guidelines and measures exploring adaptive design of the built-form within the built environment, transmission risk mitigation of COVID-19 will be much easier and more organized. To mitigate the transmission risk of diseases like COVID-19, adaptive design of built environment has become a must and it can be a major tool in pandemic control as well.

2. Literature Review

2.1. A Healthy Environment and Healthy Building

Environment is the surroundings or conditions of an area where people live. For living a healthy life, there is

no alternative of a healthy environment. An environment is referred to as healthy when the natural cycle goes side by side and there is no disturbance in nature's balance. A heathy environment helps human beings, animals, and other living things to grow and develop naturally.

According to the World Health Organization (WHO) (1946), "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". By the implication of this definition, a healthy building is actually a built environment that encourages positive well-being of human beings those reside in it. Rousseau and Wasley (1997) identified several dimensions of positive well-being, which include lighting, air, thermal comfort, aural comfort, spaces, colour and texture. Asper their suggestions, a healthy building should optimize these dimensions for occupants. Apart from quantifiable physical dimensions, Samuelsson (2000) also emphasized the importance of subjective elements in healthy buildings such as aesthetic job satisfaction and social relationships; as in [1].

A building should have some environmental qualities so that it can be justified for the healthy settings of living environment and defined as a healthy building. Mentioned in [1], the qualities are:

- A healthy building should not be too densely populated
- Its window design and layout should facilitate natural ventilation and penetration of daylight
- It should be isolated from noise and air pollution sources
- Its water supply and waste discharge system should be properly installed, maintained and managed
- Its environmental conditions should be clean and hygienic.

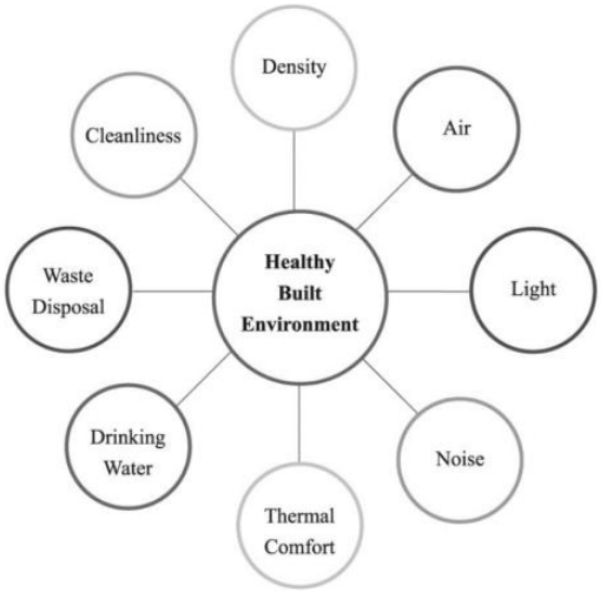

Figure 1. Environmental qualities of a healthy building: a general framework; as in [1]

2.2. Relation between Pandemic and Built Environment

Built environment is the human made environment or collection of environments constructed by humans. It includes human made structures including building, road, public transport and other human-built spaces. Built environment has serious impact on human health as most of the people spend more than 90% of their day to day lives within it. To assess the potential transmission dynamics of COVID-19 within human behaviours, it has become vital to understand the built environment including building factors and spatial relations which probably promotes or mitigates the transmission risk of COVID-19.

As built environment consists of most of the things from the surroundings, it can play a major role during the pandemic. The features of our indoor environment which can affect our health and well-being include noise, temperature, humidity and mold, light, air quality, lead paint, electromagnetic and radiofrequency radiation and water quality. While moving through the built environment, individuals come in direct or indirect contact with objects and surfaces around them. An individual with COVID-19 shed viral particles before, during and after developing symptoms; as in [2] and [3]. Built environment is responsible for inducing close interaction between individuals and objects carrying infectious diseases through various medium like the transfer of the air; as in [4]. Also, sharing workplaces or spaces have been introduced rapidly in last few years. These type of shared spaces and co-work environments in built environment may increase the transmission risk and add complexity to enacting social distancing measures. So, relation between built environment and pandemic is really a matter of concern.

2.3. Hygienic Solution of Built Form

Hygiene generally refers to the set of practices associated with the preservation of health and healthy living. The focus is mainly on personal hygiene that looks at cleanliness of the hair, body, hands, fingers, feet and clothing. Good hygiene habits are directly related to less illnesses and better health. Poor hygiene habits, however, can lead to some minor side effects. They can also lead to more troublesome or even serious issues. The health emergency caused by COVID-19 has affected all individuals in varying degrees. Considering washing hands with soap and clean water as one of the most efficient ways of infection prevention, many governing bodies have implemented a set of measures to mitigate the effects of the crisis in relation to water, sanitation, and hygiene services.

While the spread of COVID-19 is a rapidly developing situation, there are steps that can be taken, inside and outside the built environment, to mitigate the spread of this disease. As mentioned earlier, on an individual level, proper handwashing is a critical component to control the spread. To ensure more safety, it is necessary to keep the surrounding clean and maintain proper hygiene within built environment. A proper and strategic design guideline incorporated in a healthy building can considerably increase the immune system of human body, which would be an effective approach to fight against pandemic like COVID-19.

3. Methodology

This paper follows mixed method approach with cross sectional design. An experimental nature of certain tools

has been used here to understand the requirements for the mitigation of COVID-19 transmission. It is decided to take qualitative and some sort of quantitative approach to research. Primary and secondary data analysis method have been applied in this process. Hundred responses are selected randomly. For the Primary data collection, the survey tool participating close ended questions has been conducted. Approximately 10 minutes has been taken to complete each questionnaire during the period of 15th June to 30th June 2020. The questions are divided in two parts including knowledge and awareness about COVID-19, current condition of personal and building hygiene, precaution and prevention of risk towards COVID-19. To read and answer all the questions, sufficient time is given to all the respondents.

The definition of the assessment is preceded by some comparative analysis on sustainability and hygiene issues of international levels to evaluate the quality of built environment for individual health as mentioned in [5]. Although some tools are focused on energy and sustainability topics but the issue of health, hygiene and wellbeing is widely recognized as the holistic approach and suggested by the 'Health Strategy' adopted by the European Union in 2007;as in [6]. In this regard, this research method has been carried out to know the aspects of occupants' health and indoor comfort with the aim of mitigating the transmission risk of COVID-19 in built environment.

4. COVID-19 Scenario within Built Environment

Built environment has a severe effect on the transmission of COVID-19 disease. There is an immense connection between this disease and the built environment. Nowadays the development of building sector and its surrounding environment has made us realize to rethink about our way of design perspective and approach. As more than 85% of the people spend their lives within the built environment, it has become vital to understand and examine the transmission risk of COVID-19 within it. It is also important to analyze the attitude of human behavior and building operative factors in order to mitigate the spread of the disease.

A questionnaire survey has been conducted among the people living in different areas as shown in Figure 2 to understand the current scenario within the built environment as it is the major one through which people come in contact with this type of contagious disease.

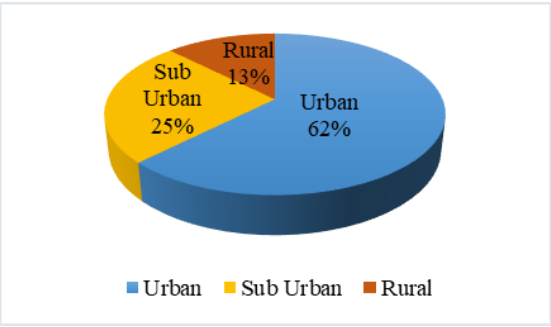

Figure 2. Percentage of participants in different areas

4.1. Condition of the Indoor Environment

Environmental qualities that are related to the occupant's health work to enhance the quality of living. The increase of wellbeing and decrease of illness would happen on depending the condition of the good indoor environment. Good indoor environment leads to healthier indoor environment and healthier indoor environment helps people to fight against infectious disease like COVID-19.

4.1.1. Air Flow

Air flow is one of the main climate factors of indoor environment. Poor indoor air quality leads to various health problems. In Bangladesh, most of the inhabitants face this problem. The houses where they live in don't have proper ventilation. The survey shows that about 65% people do not have proper ventilation in their respective houses whereas air circulation or ventilation can play a role in reducing disease transmission. By increasing the amount of air flowing inside from the outside and the rate of air exchange in indoor can make the virus particles weaker [7].

4.1.2. Lighting

Light is another climate factor of indoor environment. It helps to control and mitigate the transmission of contagious diseases. As dark places tend to hold more dust, the illuminated bright places receive less dust and virus particles within it [8]. In every house, ensuring adequate natural light is a need. Both sunlight and daylight are included in natural light. The surrounding places of our living spaces also need the provision of the proper natural light whereas, maximum houses do not have enough daylight even in daytime.

4.2. Adaptive Intervention of Built Form

Built environment has the most rapid transmission risk of COVID-19 and this issue has influenced some major changes within the built environment and the built form as well. The regular using spaces have turned into monotonous spaces where people cannot lead their long-practiced daily life like before. Some new adaptive spaces have been introduced in almost everywhere to merge with this covid-19 scenario.

4.2.1. Shared Workplace

People are working from home because of the pandemic crisis. In a survey, it has been recorded that about 52% people started working from home because of this pandemic; as shown in Figure 3. Also, a large number of students are studying from home through virtual classes. Most of them are living in Apartment (58% of them) while rest of them have individual houses; as shown in Figure 4. In this situation, these people need some defined or organized space to continue their work. As the houses or apartments are not designed in considering this new issue, the living spaces do not have any particular space like that.

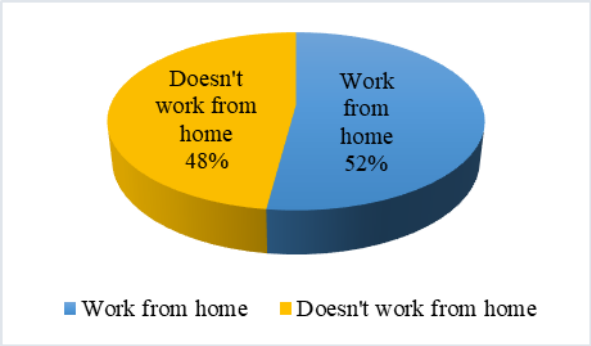

Figure 3. Percentage of people working from home

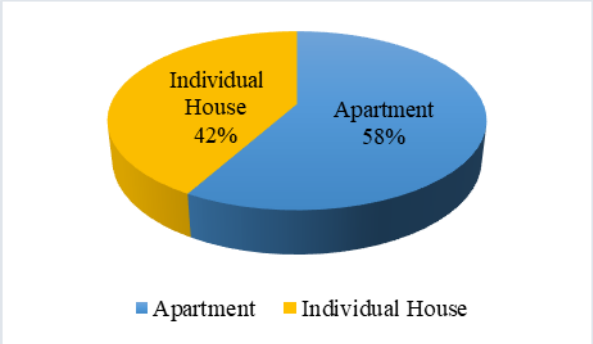

Figure 4. People living in individual house or apartment

4.2.2. Isolation Space

COVID 19 patients are suggested to stay in a separate room of the house with attached washroom facilities. This isolation process helps the patient to recover and maintain the immune system. Also, this space helps to protect other inhabitants or family members living in the same house from this infectious disease. Space with adequate sunlight and air flow plays a significant role to boost up the patient's immune system along with mental health [8]. To protect family members from this pandemic, people need this type of space. In other words, they need some particular spaces which can be modified in case of need of a isolation space or any kind of emergency and again arrange it back to previous regular space when it is no longer needed.

4.2.3. Open Relaxation Space

Infectious diseases like viruses have created a concern to rethink and design the built form according to the increasing need of open spaces as open spaces give inhabitant a way of connection to the outdoor environment. The orientation of a building and the spatial configuration of spaces should be maintained related to the climate and context of the concerned place. These changes or modification in built form could help us to improve physical and mental health.

Open spaces with certain enclosures can work as relaxation space. In a survey, it has been observed that about 90% of the people (shown in Figure 5) agreed with that they need relaxation space within their house or apartment. The existing built form of houses do not have the access of relaxation space and they are badly in need of that space especially in these COVID-19 circumstances. Around 34% people are saying to have green space within their built form and in some case, they need a verandah, rooftop access, terrace or any kind of small space to relax themselves as shown in Figure 6. Also, these open spaces sometime help to develop social interactions by maintaining social distances.

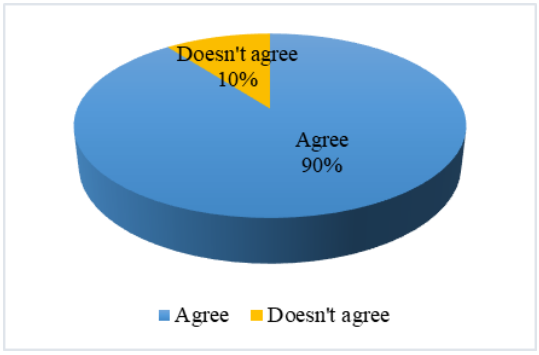

Figure 5. Need of relaxation space within built form

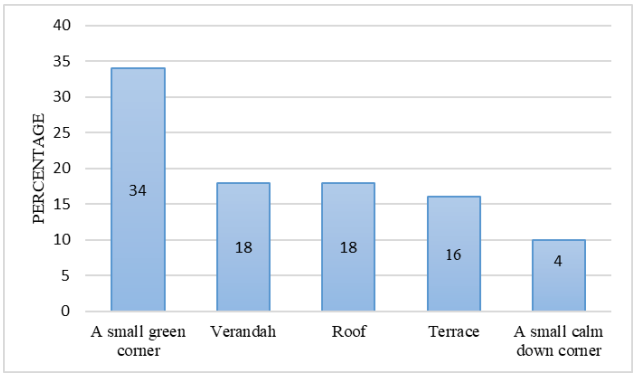

Figure 6. Types of relaxation space as per people need

4.3. Hygiene Issues

In case of designing built environment, hygiene is a significant factor. Building design approaches and planning have a vast influence on the transmission of diseases most importantly the infectious diseases like COVID-19. Also, public health is an important issue that should be taken care of in designing and planning of built forms along with the built environment.

In the questionnaire survey, 85% people (shown in Figure 7) have agreed on the issue that it is possible to reduce the transmission risk by maintaining hygienic solutions. Moreover, 38% of the people think that they are living in unhealthy environment where the hygiene issue is rarely maintained as shown in Figure 8.

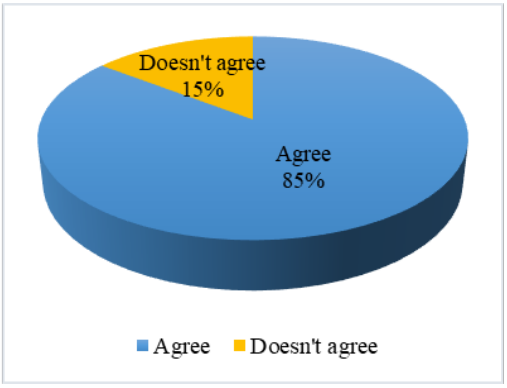

Figure 7. Maintaining hygienic solutions can reduce transmission risk

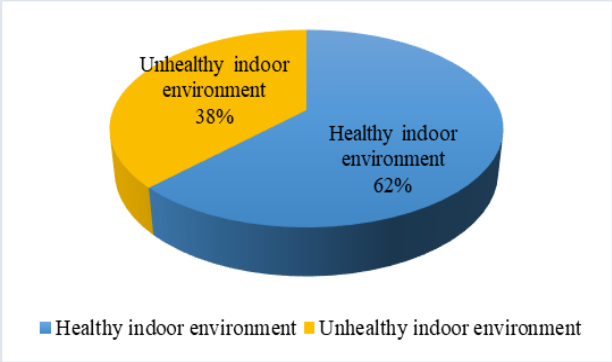

Figure 8. Data of healthy and unhealthy environment

4.3.1. Personal Cleanliness

Unhealthy and unclean environment surely lead to various diseases but to make the surrounding environment clean, people should start from their personal cleanliness. Personal cleanliness is a continuous act which helps to improve good health and keep away diseases. In case of preventing diseases like COVID-19, it is necessary to maintain personal cleanliness at first. Also, it has an effective impact on the built environment as in a broader sense one actually lives within the built environment.

4.3.2. Washing Area

Washing area or wash zone of a house is the main operational space to directly fight with diseases but the spatial relation of washing area with other spaces are not maintained properly. Nowadays the typical floor plans of houses are mostly messed up with this important issue. Also, the foyer which needs to be present after the entry of a house plan is absent in the new apartment floor plans. In another words, the traditional and rational practice of zoning was being recently modified a lot but in terms of following the new trend, the important values and practices are left behind. In a survey, it has been recorded that 46% of the people agreed that several parts of built forms (shown in Figure 9) need modification in case of maintaining hygiene issues.

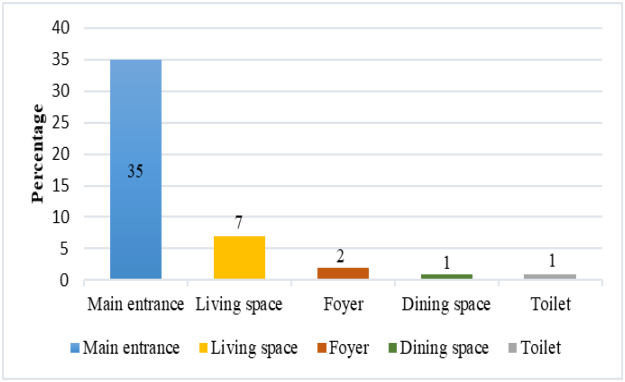

Figure 9. Need of modification in the part of built forms regarding hygiene issue

4.3.3. Building Health

Building health is a serious issue like public health. People of different sectors like Environmentalist, Public health care workers, Engineers etc. are concerned about this issue. A building with good health itself will provide its inhabitants good health facilities. People use the buildings to live in along with a huge number of other activities. Not only the rooms but also the corridors and means of communication of the buildings should be proper lighted and ventilated through the connection of natural light and air. Also, buildings with green spaces or vertical gardening are good for the health of its inhabitants. These facilities can ensure fresh air and provide people a view of green nature. Moreover, healthy building helps to increase climatic efficiency. By bringing nature into the indoor spaces these buildings help people to interact with the outer world. The built environment where people currently live is lack of this necessary facility and thus people are facing attacks of so many contagious diseases.

5. Result and Discussion

Nowadays, it has been essential to protect the built environment from the harmful contagious diseases. Built form within the built environment is also needed to keep safe and sound as people live in it. The pandemic crisis has opened a vista to rethink about our living attitudes from another perspective. After the brief discussion and result of the physical survey about the COVID-19 scenario, several design considerations have been proposed along with some possible design solutions and guidelines to ensure the safety of public health within the built environment.

5.1. Indoor Environment Quality

Indoor environment quality is a great factor to improve both physical and mental health including self-immune power. To improve immune system and mental health, indoor environment quality should be maintained according to the highest efficient way. There are some issues about indoor climate efficiency like proper ventilation and sufficient natural light. The easiest way to get efficient air and adequate light is to have large openings or windows (shown in Figure 10) and a healthier building should have proper lighting and air circulation to make the indoor environment healthy and comfortable.

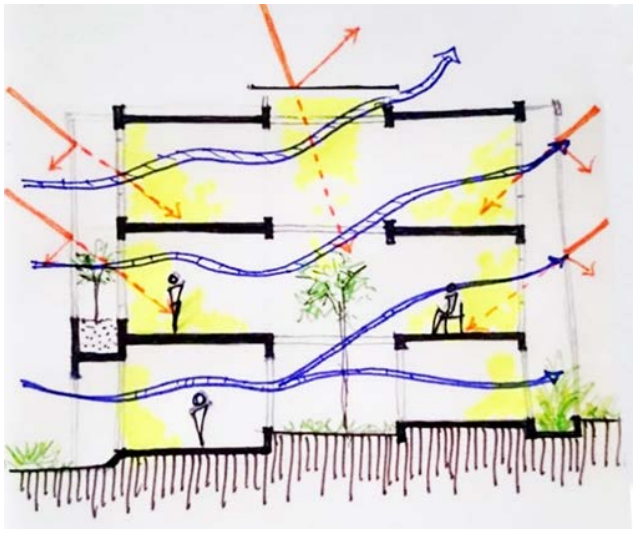

Figure 10. Natural light and ventilation

To reduce the transmission risk of COVID-19, adequate natural light in the surrounding built environment can be a great help. The sunlight should enter in every single room at least for some period of the day. If it is not possible to ensure sunlight, people should be careful about the penetration of sufficient daylight in every room of the house.

5.2. Building Designing Measures

People need to modify the built forms to improve the condition of the built environment. In this regard, hygiene issues should be maintained properly from the starting level of individual household to the highest level of built environment. For example, one needs to start modification from the smaller but significant parts or spaces of the households such as entrance, washing area, toilet, living room etc. Some adaptive measures (shown in Table 1) can be taken to improve the quality of the built environment in which the built forms reside in.

Table 1. List of Adaptive Measures and Their Impact

Adaptive Measures	Impact
Modification of the entry area with washing facilities	Hygiene level can be maintained at the earliest time
Washing area at the very front of the built form	Keep away germs and viruses
Changing the location or zoning of the washing area	Way of cleaning thyself before entering the other parts of the house
Multi-functional space	Function as workspace or any other space in terms of need
Provision of modification of built form	Easy to turn into isolation space in case of emergency
Providing relaxation space (Verandah, Terrace, Roof, Small green corner of house etc.)	Improve both physical and mental health
Sensor based fixtures or devices	Improve the common sharing building services to avoid the touch of switch, button, doorknobs, surface etc.
Placement of wash basin and hand sanitizer	Keep the built environment safe from contagious diseases
Defensive layers of hygiene precaution	Start from the main entry and end at the washing area of a house

5.2.1. Entrance

The entrance of a building or entry space of a house should be installed with amenities or being modified to maintain the hygiene so that everyone can clean hands and get wash facilities when coming from the outside. This little change or modification can help people to protect themselves and others from germs and eventually harmful contagious diseases.

5.2.2. Washing Area

Almost every apartment of cities has the same spatial zoning for entry and wash area. The distance between these two zones is quite large that germs and viruses could easily spread up to others from the person who passes that distance from coming outside. Best suited zoning along with the orientation is needed to make it work for every typical apartment floor plan as the most possible hygiene solution.

5.2.3. Shared Workplace

Because of the COVID-19 pandemic, it has become necessary to stay home and continue office or schoolwork from home as well. So various professionals need some space that can be named as workplace. In this current situation, this space can be some multi-functional or changeable space that can be modified according to the user need. Also, any suitable corner of a house would be perfect for shared workplace.

i) Creating a threshold: Threshold is a designated space in any house or room where the work physically begins and stops; as in [9]. It gives a sense of stepping into an office or workplace. It may not block the noise of surroundings, but it can create a visual indicator that works in session to other occupants. An elevated loft space or mezzanine floor can be used as threshold if a closed or separated room is not possible in current living situation. The level change points out a new zone there. Also, a shared workspace can be as simple as changing the floor texture, rearranging the furniture placement and giving signal to different space to identify the change of space to other inhabitants.

ii) Welcoming the light: Light is a space defining tool. A small amount of natural light can fill up an area and elevate the mood. View from window to the exterior helps to ease up the mind and can be aided in contemplation and meditation. Like that, home offices with a window can make the working environment more effective. Welcoming the natural light and the beauty of exterior within the working area can be extremely powerful and it can affect overall the productivity. In a word, a productive home office can be set up by allocating a distinct workspace with good light.

iii) Pinup area: Allocating a pinup area into a room can be a space for visual thinking and it can be a display of inspiring works or any blank space which can be fill up with different ideas; as mentioned in [9]. By locating this space to a home office can help to categorize the work or complete a personal to-do list.

iv) Organizing technological equipment: Arranging all the equipment needed for office environment can ease the work. Everything which is needed for regular basis can be organized close to the workstation. Provision of extra horizontal space with workplace to arrange equipment can be an effective decision for home office and schoolwork.

v) Personal productivity style: Combination of open and closed shelving with multiple work surface can be efficient when more than one person is sharing the same space. Leaving enough objects on workspace can motivate to work. Sometime visual cutter helps to define the work line and build a productive area.

5.2.4. Isolation Space

A separated living space with sleeping, eating and washing facilities named as isolation space is needed in case of clinical phase or treatment of COVID-19 disease. The regular plan of a house should have the provision to create that kind of space in case of emergency. Modular spacing system and panelled moveable facade or wall can be introduced as a solution of making isolation space through the regular floor plan. Also, the isolation space

must be well lighted and ventilated to improve the physical condition of the user.

5.2.5. Relaxation Space

To cope up with so many sudden changes in lifestyle, people are badly in need of relaxation space. Relaxation space is good for the development of physical and mental health. Also, relaxation space can work as another tool to fight against COVID-19. From the physical survey, several preferable relaxation spaces have been addressed such as verandah, terrace, roof etc. Even a small green corner and a calm corner of a house are also in that list.

5.3. Neighbourhood Hygiene Maintenance

Neighbourhood is basically the area where we are living in. Most of the time health issues are not maintained properly in neighbourhood scale. Neighbourhood or community health issue is an important key to prevent contagious diseases. Due to the unhygienic condition of the neighbourhood, the COVID-19 disease is spreading fast. The transmission rate has its topmost speed just because of the lack of hygiene maintenance within the built environment surrounding us. This unhygienic condition can provoke the existence of contagious virus. Maintenance of hygiene in neighbourhood level can prevent the spread of COVID-19 and help to keep the hygiene in built forms as well.

5.3.1. Means of Communication

The means of communication or circulation of a building is the most common platform where people get the scope to socialize with others. But the concerned places such as stair, lift, parking lot etc. are in the highest risk of transmission because of the contagious diseases. To improve the situation and continue the social communication, these places need to be modified.

5.3.2. Socialization

Social communication between person to person, family to family or person to family is important for the betterment of health but to maintain this in current situation, some guidelines are needed. Social distancing policy is a good one in this case. But communication gap cannot be afforded to maintain that policy as knowledge and awareness can easily be circulated by socialization. The social practices cannot be stopped rather it should be conducted under curtained guided way or proper directions.

5.3.3. Reduction of Transmission Risk

Each built form within the neighbourhood needs design considerations to reduce the transmission risk and cope up with the new scenario. Also, some groundwork from the local community level can be effective to mitigate the transmission risk.

i) Planning: Open planning approach can be adopted to design the neighbourhood or the surrounding built environment as confined and enclosed spaces cause poor ventilation. This type of approach can be a great help to mitigate the transmission risk.
ii) Healthy building: Climatic issues related with healthy building is good for public health and this type of building within the built environment can work as a tool to control pandemic like COVID-19.
iii) Placement of wash basin and shoe cleaning tray: Each area needs some equipment or installation like shoe cleaning tray or wash basin at the very front door to reduce the transmission risk at a certain level.
iv) Community control: Administrative body of a community or a certain neighbourhood area can make socio-economic policies to mitigate the transmission in community level. To control community transmission, local authorities can adopt different measures such as improving infrastructures, increasing water facilities, appointing health workers, involving volunteers, creating awareness etc.

6. Conclusion

COVID-19 pandemic has ranked itself as the most concerned issue of the world. It has disrupted the normal regular life and left no choice but to adopt the new changes with best possible solutions. At this critical stage, adaptive design regarding various building measures of the surrounding built environment is a vital factor to maintain the hygiene solutions. Issues related to adaptive design of the built form and indoor environment, modification of regular spaces and maintenance of hygiene in every sector can help to reduce the transmission risk. The rapid growth of the novel coronavirus can be controlled by slowing down the transmission. Key issues related to COVID-19 transmission risk and some guidelines for the precaution of this infectious disease are addressed in this paper. The paper also develops an assessment framework for the public health considering the built environment. This framework is essentially a strategic tool to provide useful information regarding the effect of the built environment on public health during COVID-19 pandemic. To mitigate the transmission risk, it is high time to adopt the design measures and act accordingly.

Acknowledgements

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References

[1] D.C.W. Ho et al., H.F. Leung, S.K. Wong, A.K.C. Cheung, S.S.Y. Lay, W.S. Wong, D.P.Y. Lung, K.W. Chau (2004) *"Assessing the health and hygiene performance of apartment buildings"* Facilities, Volume 22, Number 3/4, pp. 58-69.

[2] Yaqian M, Lin W, Wen J, Chen G. 2020. *Epidemiological and clinical characteristics of SARS-Cov-2 and SARS-Cov: a system review.* Infectious Diseases (except HIV/AIDS). medRxiv.

[3] Rothe C, Schunk M, Sothmann P, Bretzel G, Froeschl G, Wallrauch C, Zimmer T, Thiel V, Janke C, Guggeemos W, Seilmaier M, Drosten C, Vollmar P, Zwirglmaier K, Zange S, Wolfel R, Hoelscher M, 2020. *Transmission of 209-nCoV infection from an asymptomaic contact in Germany*. N Engl J Med 382:970-971.

[4] Leslie Dietz, Patrick F. Horve, David A. Coil, Mark Fretz, Jonathan A. Eisen, Kevin Van Den Wymelenberg (2020) *"2019 Novel Coronavirus (COVID-19) Pandemic: Built Environment Considerations to Reduce Transmission"* mSystems, Volume 5, Issue 2, e00245-20.

[5] Bauer M, Mösle P, Schwarz M. *Green Building: Guidebook for Sustainable Architecture*. Berlino: Springer, 2009.

[6] Commission of the European Communities. *White Paper Together for Health: A Strategic Approach for the EU 2008-2013.* http://ec.europa.eu/healtheu/doc/whitepaperen.pdf (accessed december 03 2012).

[7] COVID-19 and the built environment: Examining how building design can influence disease transmission. https://www.sciencedaily.com/releases/2020/04/200410162450.htm.

[8] Fahimipour AK, Hartmann EM, Siemens A, Kline J, Levin DA, Wilson H, Betancourt-Román CM, Brown GZ, Fretz M, Northcutt D, Siemens KN, Huttenhower C, Green JL, Van Den Wymelenberg K. 2018. *Daylight exposure modulates bacterial communities associated with household dust.* Microbiome 6: 175.

[9] https://www.forbes.com/sites/houzz/2014/01/02/6-ways-to-define-your-workspace-at-home/#2e6965b049e0..