Guidelines for submitting papers to the MX2021 – Rio Congress (Housing post-COVID-19: Design challenges)

Green housing design, COVID-19 pandemic, Adaptive architecture.

How does the pandemic influence the way we live after COVID-19? As designers, there are some opportunities for us to respond to this change. The COVID-19 crisis has shown the need to improve both the interior and exterior of housing design. This situation demands that the construction sector promote cleaner production, more resilient buildings and social equity and wellbeing. The paper aims to analyze an extensive literature review of architectonic strategies for housing after COVID-19 and apply the strategies to improve the layout of a case study in México in the early phase of the design process considering post-COVID 19 challenges such as more flexible interiors, proper home office spaces and the outdoor area. The research promotes the implementation of green technical solutions in the housing design to improve the environmental, safety, health and comfort aspects of the house. Both, propose more flexible and sustainable housing designs and contribute to users wellbeing.

1. Introduction

Since the COVID-19 pandemic took hold in late 2019 and early 2020, people worldwide have been spending far more time in their houses than usual. The crisis has blurred the lines between living, working, exercising, socializing, etc, and laid bare some long-standing points with housing design, especially in cities, where space is expensive and reduced. Thus as designers, there are new challenges and with it opportunities to respond to these changes that the COVID-19 pandemic has accelerated. For example, an increased acceptance of working from home, a boost in sustainable materials research, the necessity of outdoor green spaces and a shift towards local production and self-sufficiency. Designers have a pivotal role in pushing positive transformative change across the sector: sustainable design and wellbeing.

In the housing sector, the emergence of the COVID-19 pandemic renewed its role in supporting family ties and the psychological, spiritual, social and cultural aspects, customs and traditions of individuals and families (Bettaieb, D.M. & Alsabban, R., 2021). Analyzing the spatial design strategies it is possible to divide in comfort, health and safety and environment categories the challenges to help to develop a more sustainable housing designs post- COVID-19.

This article is organised as follows. The literature review presents a compilation of important challenges resulting from quarantine for housing design due to the COVID-19 pandemic. Then, the

methodology is presented and applied using one case study located in Tijuana, México. Last, the results and their discussion are provided, followed by the conclusions and recommendations. It is important to take into account that as the topic is fairly new, new data and information is assessed and developed continuously.

1. Literature review

1.1 Housing design post-COVID-19 pandemia

What about housing design? According to Salama A.M. (2020) in investigating the concern of post-pandemic housing spatiality the necessity of new ways of living and working will demand appropriation and adaptation of the existing spaces and new standards and specifications for new living and working settings. Therefore, considering design flexibility as an option to the changing circumstances (Lans, D.W. & Hofland, I.C.M., 2005) could play an important role in achieving the compatibility of the changing relationships between events, context, and use of space (Hill. J., 2003). The housing design is generally controlled under a set of requirements for spatial regulation (Ministry of Municipality and Rural Affairs, 2019) and several parameters in construction codes to ensure safety, security and public health in addition to a set of architectural requirements including room dimensions, interior space heights, ventilation shafts, among others. These requirements are an important reference for general design considerations and an effective source in achieving maximum quality design housing. However, after the COVID-19 pandemic, it has been demonstrated that developing an efficient housing design goes beyond just following constructive regulation (Femenias, P. & Geromel, F., 2019). Taking into account the requirements of the quality of life of individuals and families in the framework as dictated by the psychological, social and cultural dimensions, customs, and traditions is key for a more sustainable housing design (Zivkovic, M. and Jovanovic, G., 2012; Femenias, P. & Geromel, F., 2019). As part of the housing efficient design performance framework, in this research 3 categories and 5 subcategories of design challenges were identified to improve the quality of housing design (see Table 1).

The validations of these categories were performed by analyzing the scientific literature worldwide from the Scopus database. Future scenarios involving upcoming pandemics cannot be predicted, as the nature of the COVID-19, as well as its spreading behaviour, are still being researched. Nevertheless, humanity should be ready for possible future pandemics. Therefore, it is crucial to understand the requirements under pandemic scenarios and design resilient solutions. Future work can proceed in (1) the development of novel building codes and green certificates for the post-pandemic housing design (2) the modification of existing codes and certificates considering particular pandemic needs (Tokazhanov, G. et al., 2020).

During the COVID-19 pandemic, people were forced to sleep, eat, work, exercise, and socialize, all at home. This leads to one conclusion: flexible and healthy living spaces that overlook green areas need to constitute the focus of sustainable housing design strategies.

Lockdowns from COVID-19 remind us of the necessity to make the built environment resilient, including outdoor spaces, but especially homes, offices, public buildings, and other indoor spaces (Kaklauskas, A. ., 2021). For example, the lockdowns have resulted in much greater consumption of household energy and water due to the increased time people spend at home. One example is the 30% increase in energy consumption during the daytime, as per U.K. (Ref.). In the study of Kaklauskas (2021), the authors analyze satisfaction and dissatisfaction across ten UK housing typologies, a representative in this and other contexts. Lack of regular physical exercise, lack of vitamin D from sunlight, excessive food consumption, mental health concerns and issues with indoor air quality are the general health concerns in this extended period of lockdowns and restricted mobility. In addition, excessive noise from upper floors in blocks of flats or shared walls and gardens/communal spaces in closely-spaced residential areas, and issues of privacy to maintain social distancing measures are the other concerns discussed. Consequently, it is important to ensure sustainability in housing design to improve the quality of life and health outcomes (Tleuken, A. et al., 2021).

Along with the lessons learned from COVID-19 and the literature review analysed, there are challenges in the housing design requirements, which can be grouped into the following : (1) Comfort, (2), Health and safety and (3) Environment (See Table 1).

1.2 Housing Comfort categories

1.2.1 Structural flexibility

Structural flexibility relates to the property of the building structure to accommodate changes in use by providing sufficient space as well as load-carrying capacity and letting changes in one more of the building layers without the requirement to change the whole structure itself (Malakouti, M. et al., 2019; D'alessandro, D. et al., 2020; Kang, K. 2020; Rizzato, 2020; Tokazhanov, G. et al., 2020; World Health Organization, 2020; Bettaieb, D.M. & Alsabban, R., 2021; Kaklauskas, A. et al., 2021; Ogundehin, M., 2021).

1.2.2 Functional flexibility

Functional flexibility relates to the possibility of layout intervention without affecting the main structure of the house. It does not require significant expenditure for implementation but can be related to the different dimensions of the rooms when matching new spaces and meeting new requirements without

additional expenses. Consider, for example, sliding doors and movable walls that can close off or open up certain spaces for different indoor/outdoor activities as needed (Hill, J., 2003; Lans, D.W. & Hofland, I.C.M. 2005; Raviz, S.R.H et al., 2015; Mahdinejad, J. E. D., & Ehsani Oskouei, S. F. 2016; Clair, A., 2020; D'alessandro, D. et al., 2020; Gilani, G. and Türker, Ö.O. 2020; Kang, K. 2020; Ogundehin, M., 2020; Rizzato, E., 2020; Tokazhanov, G. et al., 2020; WOH, 2020; Bettaieb, D.M. & Alsabban, R. 2021; Kaklauskas, A. et al., 2021).

1.3 Housing Health and safety categories

1.3.1 Improved transition zones

Given the increased focus on hygiene and sanitation, we could see a desire for terraces, porches, foyers and other outdoor entrance vestibules that ease the transition from outside to inside the home. This space, which might be separated from the rest of the house, could include easy-to-clean flooring and built-in storage for shoes, coats and sanitation products. Also, could include new spaces such as mailrooms for functions as online shopping (Clair, A., 2020; Kang, K. 2020; Ogundehin, M., 2020; Rizzato, E., 2020; Tokazhanov, G.et al., 2020).

1.3.2 Outdoor/indoor green areas

Lockdown measures have shown how crucial outdoor space is to people's wellbeing. On the one hand, there are more user-friendly communal gardens and terraces combined with private outdoor spaces projecting balconies for summer/winter gardens, creating an area that can be enjoyed all year. On the other hand, indoor greenery could help to improve indoor air quality in our homes and reduce stress (D'alessandro, D. et al., 2020; Kang, K. 2020; Ogundehin, M., 2020; Rizzato, E., 2020; Tokazhanov, G. et al., 2020; Block, I., 2021; Kaklauskas, A. et al., 2021).

1.4 Housing Environment category

1.4.1 Passive design strategies

Passive design strategies take advantage of natural opportunities as they relate to the location of the building's site, the local climate (site's microclimate), the properties of building materials, etc. For example, passive design strategies could include: facade design and orientation, natural indoor ventilation, noise isolation, natural indoor lighting, renewable energy, water efficiency and the selection of carbon smart materials (Zivkovic, M. & Jovanovic, G., 2012; Femenias, P. & Geromel, F., 2019; Abergel, T. et al., 2020; D'alessandro, D. et al., 2020; Lak A. et al., 2020; Mukherjee, A. et al., 2020; Rizzato, E., 2020; Tokazhanov, G. et al., 2020; Block, I., 2021; Kaklauskas, A. et al., 2021; Tleuken, A. et al., 2021; Carbon Smart Materials Palette., 2021).

Table 1: Summary of expected challenges to develop a sustainable housing design alternative post- COVID-19

Category	Subcategory	Description	References
Comfort	Structural flexibility	Structural flexibility relates to the property of the building structure to accommodate changes in use by providing sufficient space as well as load-carrying capacity and letting changes in one more of the building layers without the requirement to change the whole structure itself.	Malakouti, M. et al., 2019; D'alessandro, D. et al., 2020; Kang, K. 2020; Rizzato, 2020; Tokazhanov, G. et al., 2020; World Health Organization, 2020; Bettaieb, D.M. & Alsabban, R., 2021; Kaklauskas, A. et al., 2021; Ogundehin, M., 2021
	Functional flexibility	Functional flexibility relates to the possibility of layout intervention without affecting the main structure of the house. It does not require significant expenditure for implementation but can be related to the different dimensions of the rooms when matching new spaces and meeting new requirements without additional expenses. Consider, for example, sliding doors and movable walls that can close off or open up certain spaces for different indoor/outdoor activities as needed.	Hill, J., 2003; Lans, D.W. & Hofland, I.C.M. 2005; Raviz, S.R.H et al., 2015; Mahdinejad, J. E. D., & Ehsani Oskouei, S. F. 2016; Clair, A., 2020; D'alessandro, D. et al., 2020; Gilani, G. and Türker, Ö.O. 2020; Kang, K. 2020; Ogundehin, M., 2020; Rizzato, E., 2020; Tokazhanov, G. et al., 2020; WOH, 2020; Bettaieb, D.M. & Alsabban, R. 2021; Kaklauskas, A. et al., 2021
Health and safety	Improved transition zones	Given the increased focus on hygiene and sanitation, we could see a desire for terraces, porches, foyers and other outdoor entrance vestibules that ease the transition from outside to inside the home. This space, which might be separated from the rest of the house, could include easy-to-clean flooring and built-in storage for shoes, coats and sanitation products. Also, could include new spaces such as mailrooms for functions as online shopping.	Clair, A., 2020; Kang, K. 2020; Ogundehin, M., 2020; Rizzato, E., 2020; Tokazhanov, G. et al., 2020
	Outdoor/indoor green areas	Lockdown measures have shown how crucial outdoor space is to people's wellbeing. On the one hand, there are more user-friendly communal gardens and terraces combined with private outdoor spaces projecting balconies for summer/winter gardens, creating an area that can be enjoyed all year. On the other hand, indoor greenery could help to	D'alessandro, D. et al., 2020; Kang, K. 2020; Ogundehin, M., 2020; Rizzato, E., 2020; Tokazhanov, G. et al., 2020; Block, I., 2021; Kaklauskas, A. et al., 2021

		improve indoor air quality in our homes and reduce stress.	
Environment	Passive design strategies	Passive design strategies take advantage of natural opportunities as they relate to the location of the building's site, the local climate (site's microclimate), the properties of building materials, etc. For example, passive design strategies could include: facade design and orientation, natural indoor ventilation, noise isolation, natural indoor lighting, renewable energy, water efficiency and the selection of carbon smart materials	Zivkovic, M. & Jovanovic, G., 2012; Femenias, P. & Geromel, F., 2019; Abergel, T. et al., 2020; D'alessandro, D. et al., 2020; Lak A. et al., 2020; Mukherjee, A. et al., 2020; Rizzato, E., 2020; Tokazhanov, G. et al., 2020; Block, I., 2021; Kaklauskas, A. et al., 2021; Tleuken, A. et al., 2021; Carbon Smart Materials Palette., 2021

In concordance with Table 1, experts are proposing alternatives for housing design post- COVID-19. The next section summarizes different conceptual examples of technical solutions for new housing design post COVID-19 developed by different construction experts.

1.5 COVID-19 housing designs examples

1.5.1 Guallart Architects housing development

Self-Sufficient City by Guallart Architects is a concept for a housing development in Xiong'an in China, which would be able to produce its energy and food during another possible pandemic lockdown. Guallart Architects propose three essential design strategies: (1) outdoor terraces and balconies, (2) solar panels on sloping roofs would provide electricity, (3) each apartment would come with its bird box (indoor/outdoor vegetation and indoor farming).

1.5.2 Kunwook Kang housing design

Kunwook Kang from Make architects proposed four different housing design strategies after the COVID-19 crisis. The strategies include: (1) flexible interiors (sliding doors and moving panels that can close off or open up indoor spaces as needed), (2) enhanced services for home offices (mechanical and electrical provisions and more placement of sockets and other data points in each room), (3) transition zones and (4) external amenities (communal gardens and terraces, maximise an apartment's private outdoor space and winter gardens).

1.5.3 Housing design by CBT Boston

Vickie Alani, a Principal at CBT in Boston, analyses in an article for BDC network different design strategies that the company is applying in the new housing developments after COVID-19. Vickie mentioned design alternatives to incorporate elements of health and wellness, safety, flexibility, and easy access to outdoor spaces in the projects. For example, flexible green outdoor space, larger mailrooms, spacious coworking areas, outdoor sitting choices, fitness area upgrades, HVAC upgrade with MERV 13 filters and more space balconies.

2. Methodology

2.1 BIM

Building information modelling (BIM) is a collaborative work methodology that seeks to connect people, processes, and digital models in building and infrastructure projects, thereby allowing fluidity in the transfer of information and communication (Freire. J. & Alarcon, L., 2002). With a digital graphic representation of the physical characteristics and functionality of the project, it is sought to manage the phases of design, construction, and administration throughout the life-cycle, considering relevant the information associated with the graphic representation, which allows its work and use for various functions (Vitiello, U. et al., 2019). The present study generated a BIM model of an example of an standard apartment located in Tijuana, México; the layout design was adapted incorporating the challenges mentioned in Table 1 for a sustainable post-COVID-19 housing design.

2.2 Case study

The case study is located in Tijuana, a city in Baja California, Mexico. The city climate is warm and wet with an average of 28 degrees in summer and 5 degrees in winter. The projected apartment area is 63 sqm, it is a mid-income apartment category and it is a not built project from LAB Arquitectos. See Figure 1.

3. Methodology application

3.1 Conceptual Layout design

BIM is characterized by the optimization of resources, flexibility, and adaptability. The methodology proposed is used to model the apartment and improve the layout by applying the design recommendation generated by different experts in the analysis of the literature review section. See Figure 2.

Figure 1. Actual floor plan of 1 bedroom apartment. (Source: LAB Arquitectos, 2019).

Figure 2. Proposed conceptual floor plan with the application of (1) comfort, (2), health and safety and (3) environment requirements to design a housing alternative post- COVID-19 (Source: Jani F. Velazquez, 2021).

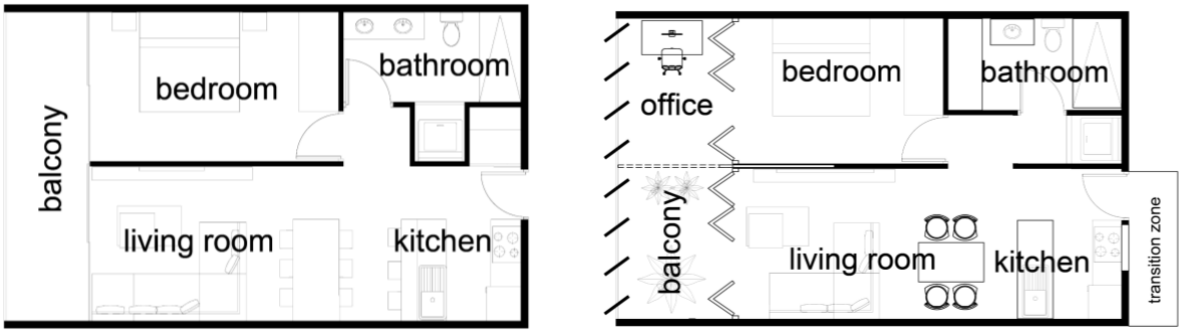
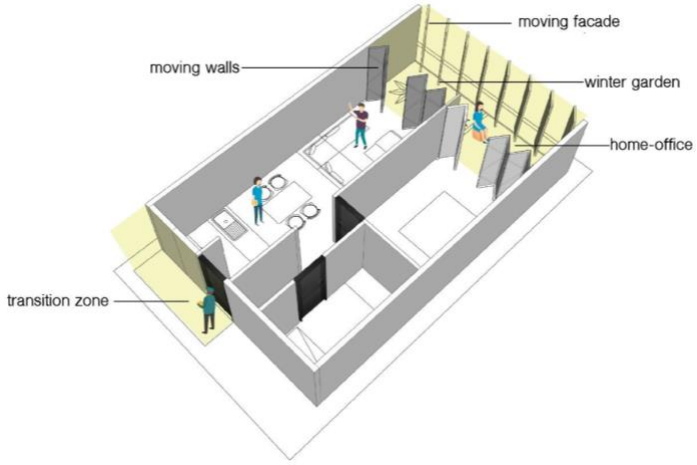
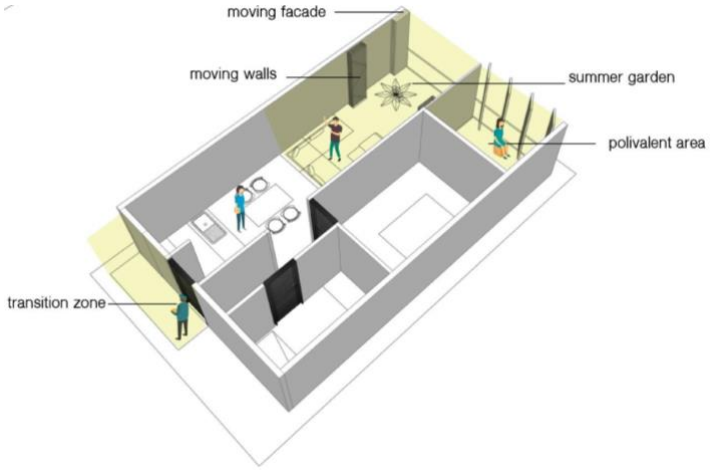


Figure 3. Conceptual 3D Model of with two alternatives of the apartment with a flexible layout design post-COVID-19 pandemic (Source: Jani F. Velazquez, 2021).



option 1



option 2

4. Results and Discussion

The research showed that the implementation of a flexible layout in a housing design could be feasible. First, the comfort category, which includes the structural and functional flexibility subcategories, showed the emerging necessity of developing a housing layout taking into account the different activities that will take place in the house by the users. For example, the necessity of a formal space to work from home or the necessity of spaces for indoor exercising, etc. It is fundamental to pay more attention to design separated and flexible spaces for future spatial requirements aiming to develop and support users' wellbeing and to find private spaces for the housing users to allow each family member to have personal spots at home. Second, the health and safety category, which includes improved transition zones and outdoor/indoor green areas subcategories, showed the necessity of the addition of green spaces into the housing design to assist to enhance the mental health of the residents, decreasing possible future psychological problems such as anxiety, stress and depression, between others. The design of transition zones such as a porch or small lobby could help to decrease the transmission of the viruses planned as a sanitizing area before entering the house. Finally, the environment category, which includes diverse passive design strategies, showed the importance of natural ventilation to maintain high indoor air quality. Another measure was the use of the movable solar protection installed in the facade to reduce the use of air conditioning in summer and take advantage of the natural lighting in winter and improve the indoor comfort conditions. These last strategies could assist to reduce energy consumption.

Furthermore, the method developed in this study aims to identify and use different design strategies that could help to improve the actual housing design taking into account future situations such as lockdowns, home office activities, new virus forms, etc.

In the future, it is suggested to do a Post-Occupancy Evaluation (POE) to corroborate if the proposed housing design recommendations meet properly the user's expectations and wellbeing taking into account environmental and economic aspects.

In summary, with the expected challenges in the housing design post-COVID-19 pandemic, a benchmark system with three categories was developed. The benchmark system combined comfort, health, safety and environment requirements to develop users' wellbeing and a more sustainable housing design. It is relevant to mention that for future research it can be enriching to calculate the reduction of energy and water consumption and CO_2 emissions per year per unit applying the different design recommendations mentioned in this article.

5. Conclusions

Housing enhancement has become a challenge in many cities after the COVID-19 pandemic. There are many aspects regarding urban planning, architecture, engineering, among others. For example, home office has become a very important topic, which requires special constructive environments such as noise isolation, natural light, natural ventilation etc. Developing a more sustainable housing design may require floor plans with more open spaces and creative locales within the home that can be designed for office use. In addition, future housing design must be healthy and energy-efficient to demonstrate resource efficiency during the entire lifecycle of a building in terms of energy efficiency, water consumption reduction, low to zero CO_2 emissions and considering user's needs and wellbeing.

It is suggested to develop additional studies about housing design and post-occupancy evaluations after the COVID-19 crisis on how the pandemia impacted the housing residents' wellbeing during and after the lockdown changing the way the people live and work. However, the research in the area of the relationship between sustainable housing design and the COVID-19 crisis is yet limited, but with opportunities to improve.

The new or rehabilitation of housing design needs to be focused on the user's wellbeing and spatial and constructive efficiency, not merely a home designed based just on different construction regulations. Drive to protect human mental and physical health became the key point in the analysis of housing priorities, with a focus on the quality of the indoor environment, space distribution and the selection of building materials. There is an opportunity to give more gravitas to affordable housing encouraging passive design and greening up buildings (Lak, A. et al., 2020)

The recommendations from the (1) comfort, (2), health and safety and (3) environment categories could assist as a basis for policymakers and designers to speaking up for new policies and actions aiming to promote and maintaining physical and mental wellbeing in healthier housing designs (D'alessandro, D. et al., 2020).

According to the literature review of this paper, in the times of the ongoing COVID-19 crisis, some housing trends for the upcoming years are as follows:

1.- Flexible Layout: Layout intervention without affecting the main structure of the house, according to the user's needs (home office, indoor exercise, school lessons and lectures, etc).

2.- Healthier spaces: Construction materials choices (low-carbon and germ-resistant materials) to assist to improve interior user's health conditions and to reduce CO2 emissions.

3.- Flexible green outdoor spaces: To improve indoor air quality, to reduce stress, and to provide different spaces to work or to socialize.

4.- Energy efficiency upgrading: Aiming to reduce operational costs and CO2 emissions improving indoor user's comfort.

5.- Transit zones and mailboxing: For online shopping and self-hygiene and sanitation.

6.-Soundproofing and privacy: Every space inside the house needs its constructive requirements to be functional, noise isolation is essential to separate areas inside the house and also to reduce noise from the neighbours. For privacy needs, the use of movable walls, movable windows and double and movable facades is suggested.

In conclusion, the COVID-19 crisis and lockdown measures have revealed the deficiencies in existing residential buildings in terms of health and safety risks, excess consumption of environmental resources, and lack of user comfort (Tokazhanov, G. et al., 2020). Nevertheless, urban planning and architectural design must define a new concept of housing design emphasized on the social aspect and wellbeing. The effects of COVID-19 demonstrated the importance of incorporating resilience into the housing configuration in the early design stage. Finally, it is suggested to build resilient housing developments, prepared for future breakdowns, with constructions that can absorb, recover and prepare for future shocks (economic, environmental & social) to promote sustainable development.

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