Creating a link between healthy homes and architectural elements: a qualitative study of modern residential buildings

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Abstract

Purpose – The aim of the research presented in this paper is to provide information on the common problems of healthy homes in the context of architectural design deficiencies. Especially because determining the status of a healthy house is particularly challenging if the design is poor.

Design/methodology/approach – Qualitative methods, i.e. interviews, site visits and graphic elicitation diagramming were used in two different stages of data collection. They were then analysed using thematic analysis.

Findings – The findings show that the architectural elements can have positive or negative effects on the health and safe environments. The quantity of doors and the use of transparent glass have largely contributed to the thermal transmission and increased indoor temperatures. The roof aluminium sheets and absence of vents inhibited indoor heat loss. This has led to discomfort and overuse of air-conditioning units, particularly during the COVID-19 pandemic where most households stayed/worked from home. The inappropriate height of the ceiling and roof made it challenging for maintenance purpose, reducing safety levels, which could result in physical injuries.

Originality/value – The concept of healthy homes is not new. Studies have been conducted in Western countries and in the field of healthcare. However, there is lack of study in built environment particularly in developing countries and inadequate inter-disciplinary and empirical research to connect the healthcare field. The pervasive and recurring design deficiencies in the construction industry remain a source of unhealthy homes, which must be addressed. Future investigations are necessary to expand the conclusions that can be drawn from this paper for health equity within the society and nation.

Keywords Design deficiencies, Healthy homes, Indoor environment, Interior architectural elements, Modern residential, Qualitative methods

Paper type Case study

1. Introduction

At the time of writing this paper, about 30 million individuals in Malaysia are enforced under the third Movement Control Order (MCO) total lockdown to stay at home as the number of COVID-19 cases spikes to an average daily high of 8,000 infections. Although this control order is essential to help fight the fatal transmission of COVID-19, the fact remains that housing can cause health inequalities. It is believed that prior to COVID-19, there were many families spending time in their homes, some of which expose them to health risks and potentially worsen pre-existing illnesses. It is noted that a healthy home provides supportive facilities, spaces and services especially for individuals with disabilities and chronic health problems. For this reason, having a healthy home and maintaining it, is necessary. For the purpose of this study, healthy

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homes is defined in a broader context as a shelter that is designed, built, renovated and maintained to promote and encourage good health ("Healthy Homes Maintenance Checklist", 2018).

To date, the concept of healthy homes is not widely discussed in Malaysia. There is almost an absence of research and attention from the government in encouraging healthy homes, compared to sustainable development. Although research outputs frequently relate sustainable development to human health (e.g. Akadiri *et al.*, 2012; Alyami and Rezgui, 2012; Kats *et al.*, 2003; Hu *et al.*, 2021), there is a lack of clarity relating these concepts and healthy homes within the built environment (Mundo-Hernández *et al.*, 2014). While it is acknowledged that the intersection of sustainability and healthy homes cannot be ignored, this study contends that the differences between the two concepts may have been overlooked. Sustainable development typically presents the need for improving the efficiency of buildings (in terms of energy, water and materials) to provide environmental care, a long lifespan, households satisfaction and value (Han *et al.*, 2010). On the other hand, healthy homes involve design choices within a specific context and empathic decision-making that can prevent diseases and injuries, and fosters the well-being of its households. Mermin *et al.* (2006) compared major national sustainable buildings, which implemented the criteria of healthy homes and found that there were differences in the extent to which various national green directives take health into account. For instance, injury prevention was not included in any guidelines, neither was contamination protection addressed consistently. A sustainable building can be expensive when it complies with the green standard requirements such as Building Research Establishment Environmental Assessment Method and Green Building Index. But a healthy home does not have to be costly especially when the common elements are sensitively and ethically considered during the design stage (Healthy Housebuilding, 2018).

Deficiencies of housing design have been argued to significantly contribute to health-threatening situations (U.S. Department of Health and Human Services, 2009). However, previous research within the built environment on deficiencies (e.g. Carretero-Ayuso and García-Sanz-Calcedo, 2018; Islam *et al.*, 2021; Khan *et al.*, 2021) have shown a greater focus in quantifying and categorising types of defects as well as their influence on maintenance and cost rather than health. In conjunction to that, designers and planners in the field of the built environment have been criticised for not fully comprehending the significance of indoor and outdoor aspects of a home construction (Srinivasan *et al.*, 2003), reflecting the overall ethical decision-making when design considerations are made. This study attempts to highlight the common problems of healthy homes in the context of architectural elements that are frequently but implicitly connected to design deficiencies. Understanding the design implications of the influencing architectural elements allows designers to accommodate people's health while also developing more ethical designs for future initiatives. The increasing emphasis on global health equality (such as through the Sustainable Development Goals) and the emergence of stay-at-home policy during the pandemic period require the need for improved healthy home standards in a country such as Malaysia. This research anticipates contributing to the regulatory bodies of the construction industry and future research in proposing strategies and methods to improve the design impacts on household health. It is necessary to clarify that the scope of this study is limited to the interior architectural elements, with the term "architectural elements" referring to windows, doors, joineries and including the finishes such as the ceiling, floor, roof and walls (Uygun *et al.*, 2011). All these are typically designed and specified by the architects.

2. Healthy homes and design deficiencies

People are noted to spend more than 80% of their time indoors mostly at home, work, school and other places (Schweizer *et al.*, 2007). The COVID-19 pandemic has significantly impacted this, causing people to spend more time at home than ever, including employed adults, children of different age and the elderly, all of who work and learn from home. To date, it is still unclear to most people how the design of their home can have impact on their health and well-being (Wheeler *et al.*, 2016). This is echoed in literature pertaining to design deficiencies which suggests that not all homes are healthy. In addition, research has provided evidence that links architectural design deficiencies to increased stress (Connellan *et al.*, 2013), risks of exacerbating chronic illnesses, morbidity and mortality (Zuurbier *et al.*, 2021), depression and distraction (Kanakri *et al.*, 2017). Behavioural abnormalities have also been acknowledged where research has provided evidence for violence and abuse at homes (Schweizer *et al.*, 2007). Design deficiencies have also been noted to negatively affect the financial stability of the households especially on the maintenance effort (Chohan *et al.*, 2011).

A further review of the literature on healthy homes and design deficiencies has revealed a number of interrelated architectural elements that have impact on households (see: Table 1). While there are many articles on deficiencies or defects, there is a limited number of research assessing the influence of building elements design on health. Healthy homes require a combination of built environment and healthcare research, yet both efforts are inadequate (Pinter-Wollman *et al.*, 2018). Considering this, a more systematic literature review comparing the scope and limits of previous studies from both fields, as well as empirical research, is required in the future to make progress towards health equity. The reviewed articles summarised in Table 1, provides in a nutshell a quick inclusion of architectural elements for this research.

Doors, windows, space, ceiling and finishes are elements that are obvious to the households and have significant impact on their restoration, stress, anxiety, motivation and pleasure (Ergan *et al.*, 2018). Previous literature (e.g. Schweizer *et al.*, 2007; Zuurbier *et al.*, 2021) suggest that inappropriate thermal movement, poor ventilation, indoor air pollution, poor air quality and insufficient natural lighting are examples of issues that can be influenced by the size, position, materials of the doors and windows. Meanwhile, other design issues such as narrow staircases, small bedroom and kitchen spaces, relative to the orientation of the sun and exposure to weather conditions, all remain issues associated with a building's layout and/or space (e.g. Musa and Obaju, 2016; Sabha, 2015). In addition, it is emphasised that the major issues for the ceiling and roof of buildings are safety and poor maintenance owing to the height (Wardle and Duncan, 2017; "WHO Housing and health guidelines", 2018). This can result in physical injuries and other health problems. It has also been recognised that the finishes frequently relate to the feelings of aesthetics and pleasure or emotions which includes quality, colour and texture (Ergan *et al.*, 2018; Fricke *et al.*, 2018). Sanitary fitting design issues discussed by previous literature are more related to the safety for children and the elderly (e.g. Afacan, 2019). While sanitary fittings were highlighted in design deficiencies articles, they received less attention because the issues discussed were more on the plumbing and sanitation that primarily focused on building services which are not relevant to this study and thus, not included. This paper addresses interrelated design deficiencies and healthy homes architectural elements that are crucial to demonstrate ethical design in the built environment, so far lacking in the scientific literature.

3. Materials and methods

This study seeks to understand the human experience with the determinants of healthy homes rather than providing experimental data on house performance. The qualitative inquiry served to be the most suitable in corresponding to the experience within a particular context and allowing meaning to be explored (Merriam, 2009). In line with that, different types and designs of houses were selected as cases, not to represent the population but to provide context-and-case dependent findings relevant to the qualitative research issue. Qualitative research examines real-world settings that determine social concerns and problems (such as health) drawing on broader conclusions (Flick, 2018). Nonetheless, because the data is not

Table 1. Key architectural elements for healthy homes

	Doors and windows	Space	Ceiling	Roof	Finishing materials	Sanitary fittings
Healthy homes literature	"Healthy Homes Maintenance Checklist" (2018), "WHO Housing and health guidelines" (2018), Krieger and Higgins (2002), Seidlein *et al.* (2019), Wheeler *et al.* (2016), Zarrabi *et al.* (2021)	"Healthy Homes Maintenance Checklist" (2018), "WHO Housing and health guidelines" (2018), Krieger and Higgins (2002), Seidlein *et al.* (2019),Wheeler *et al.* (2016), Zarrabi *et al.* (2021)	"Healthy Homes Maintenance Checklist" (2018), "WHO Housing and health guidelines" (2018)	"Healthy Homes Maintenance Checklist" (2018), "WHO Housing and health guidelines" (2018), Seidlein *et al.* (2019)	"Healthy Homes Maintenance Checklist" (2018), "WHO Housing and health guidelines" (2018), Krieger and Higgins (2002), Seidlein *et al.* (2019), Wheeler *et al.* (2016), Zarrabi *et al.* (2021)	"Healthy Homes Maintenance Checklist" (2018), "WHO Housing and health guidelines" (2018), Krieger and Higgins (2002), Seidlein *et al.* (2019)
Design deficiencies literature	Carretero-Ayuso and García-Sanz-Calcedo (2018), Islam *et al.* (2021), Musa and Obaju (2016), Peansupap and Ly (2015), Sabha (2015), Salim *et al.* (2016), Wardle and Duncan (2017)	Ali *et al.* (2013), Musa and Obaju (2016), Peansupap and Ly (2015), Sabha (2015), Wardle and Duncan (2017)	Ali *et al.* (2013), Carretero-Ayuso and García-Sanz-Calcedo (2018), Peansupap and Ly (2015), Sabha (2015), Salim *et al.* (2016), Wardle and Duncan (2017)	Ali *et al.* (2013), Carretero-Ayuso and García-Sanz-Calcedo (2018), Islam *et al.* (2021), Sabha (2015), Salim *et al.* (2016), Wardle and Duncan (2017)	Ali *et al.* (2013), Musa and Obaju (2016), Peansupap and Ly (2015), Sabha (2015), Salim *et al.* (2016), Wardle and Duncan (2017)	Islam *et al.* (2021), Peansupap and Ly (2015), Wardle and Duncan (2017)
Other architecture-health related studies	Afacan (2019), Connellan *et al.* (2013), Ergan *et al.* (2018), Fricke *et al.* (2018), Zuurbier *et al.* (2021)	Afacan (2019), Connellan *et al.* (2013), Ergan *et al.* (2018), Fricke *et al.* (2018), Zuurbier *et al.* (2021)	Afacan (2019), Ergan *et al.* (2018)	Connellan *et al.* (2013), Zuurbier *et al.* (2021)	Afacan (2019), Connellan *et al.* (2013), Ergan *et al.* (2018), Fricke *et al.* (2018), Zuurbier *et al.* (2021)	Afacan (2019)

statistically representative, it is frequently misunderstood as being difficult to generalise. Researchers (Boeije, 2010; Flick, 2018; Azevedo *et al.*, 2020; Silverman, 2020; Yin, 2017) argued that a few cases in qualitative studies allow for a detailed analysis of the contextual dimension. Silverman (2020) emphasised that generalisation in qualitative research is based upon discovering the unexpected findings and/or regularities between cases that may escape large sample studies. It was specified that identifying cases as interactive units is crucial for qualitative generalisation.

Thus, by specifying details of the house design as a unit of analysis, a major developed area in a town was selected whereby the developer has completed four phases of projects and is currently developing on the fifth. A total of 13 different house designs have been constructed by the developer since 2011, with 689 houses altogether. Cases for this research were selected based on purposive sampling, which enables the generalisation of qualitative processes based on the social representativeness of the phenomenon rather than statistical or personal rules (Gobo, 2003; Silverman, 2020). The qualifying criteria of cases to allow deductive inference on the safety of homes included houses in the same development area, but with varying completion dates and/or design. The rationale for selecting different designs is the need to capture the varied designs in the location of study. Meanwhile, different completion dates allow for the discovery of whether the design has been improved by the developer over time or whether the main design problems have been repeated despite the issuing of complaints from owners in the first phase. The developer documented the complaints regarding deficiencies of houses and made them available at their office in hard copies for screening only (no recording was permitted). Using a checklist, the data was utilised to corroborate the major findings of this study, with the support of the developer's Senior Executive from the Customer Relations Management department, who has been handling development defects for seven years. Furthermore, the criteria include only houses that have been occupied by the owner for at least six months, allowing them to settle in, become familiar with the house layout and gain more understanding of the building (see Green, 2012; London, 2012). Owners often observe more on elements that need to be modified for comfort or health, make decisions and have a sense of belonging (Grange and Ming, 2001; Smith, 2011). Out of 13 designs in the development, ten potential owners that met the criteria were approached through close contacts. The owners of other three designs were inaccessible. Nevertheless, only six owners were willing to participate in this research. The layouts of the houses chosen varied, but all were single-storey with four bedrooms, but for the exception of a terrace house with just three bedrooms (see Table 2 for the type).

Prior to the data collection sessions, participants were briefed and given an information sheet, which was critical for them to understand the motivation of this research and give their informed consent as a record of the participants' understanding of the research. Data was collected in two stages. The first stage started in June 2019 before COVID-19 hit the world. It entailed semi-structured interviews as well as site visits. Interviews were conducted first, to obtain an initial data set and to establish dependability with the participants before a site visit was sought. A total of 11 questions were structured, based on the previous literature discussed in section 2. While the themes have been predetermined, the interview questions asked were general and open-ended to avoid the biasness that led answers to the participants. For example, participants were asked: (1) How comfortable are you living in your house? (to explore the overall experience), (2) What spaces in your house do you think need to be enlarged and why? (to explore the experience relating to spaces in the house), (3) When it rains, what are the problems you normally faced with? (to identify problems related to leakages) and (4) How satisfied are you with the type of finishes used in the house? (to discover the issues related finishes, if any). Probing questions were then asked to gain a thorough understanding of any further issues. Interviews were audio recorded, except for P1 who did not allow for recording. In the case of P1, the interview was written down in notes. Site visits were conducted a week later after the interview at a date agreed and set by the participant. Site visits were carried out to augment the information given during

Participant	Type of house	Date of completion	Number of households	Land area (m2)	Built-up area (m2)
P1	Semi-detached (design A)	September 2012	5	418	167
P2	Bungalow	March 2018	7	743	186
P3	Semi-detached	December 2011	1	418	130
P4	Bungalow	July 2015	6	747	186
P5	Semi-detached with a swimming pool (design B)	September 2012	4	524	167
P6	Terrace	December 2011	4	184	84

Table 2.
Details of participants' home

the interview and to allow understanding of the actual problems affecting the households. Identified issues of the architectural elements were photographed along with basic measurements of living rooms. The visits provided visual observations in a natural environment to align with the interviews and the next stage of study. As Newhouse *et al.* (2017, p. 31) affirmed, "Site visits have the potential to generate powerful, actionable information . . . because they can produce information that is both summative and formative in nature."

The second stage of data collection was a follow-up conducted in June 2021, after a series of movement control (lockdown instances) in Malaysia. As stated in section 2, the government's policy caused people to stay at home, resulting in participants staying in their homes over prolonged durations. The purpose of data collection at this stage was to record any new issues linked to the research topic. To ensure consistency of reporting, the same participants were approached for the follow-up data collection. Four participants agreed to be included in the research. P6 had relocated to a different state before the third MCO started, hence was excluded. Meanwhile P2 did not provide input despite repeated contacts. Graphic elicitation diagramming method utilising infographic of healthy homes developed for UK-GBC (see: Wheeler *et al.*, 2016, p. 6) with a set of structured open-ended questions were emailed to the four participants. The use of graphics to stimulate responses has been shown to be effective (Umoquit *et al.*, 2008). Written feedback was returned before further discussions were conveyed via WhatsApp, which was convenient for all participants who were adhering to the social distancing orders.

All audio recordings, handwritten field notes, written feedbacks and other collected data were prepared for analysis (typed, organised, transcribed, scanned and digitally stored accordingly). Data was analysed using thematic analysis approach, adopted at an interpretative level. This involves comprehending data, identifying lessons learned and expanding beyond themes to gain a broader range of perspectives aligned with insights or previous works (Silverman, 2020). This enables the uncovering of patterns of unexpected and anticipated regularities in cases (Tuffour, 2017). As the findings may pose a possible risk to the developer and participants, they are carefully worded to contribute a broad understanding of healthy homes. The findings of the research presented in this paper are divided into two sections. Section 4 exhibits data pertaining to architectural element design deficiencies, while section 5 shows the results of other healthy homes issues after several MCOs.

4. Results: design deficiencies of the architectural elements

The most prominent problems encountered by the households were related to doors, ceiling and roof.

4.1 Doors

All participants highlighted the damaged of their main entrance door or laminated timber floor near the door because water penetrated the house when it rained (Plate 1a). Majority of them stated that it got worse due to the strong wind and heavy rain in that region, as well as absence and/or insufficient span of roof eaves (see Plate 1b).

Participant P3 was concerned about security, after robbers broke through the neighbour's door. Likewise, P6 indicate security concern, because the quality of sliding lock sets of the main doors were poor and to break-in the house is easy (Plate 1c). On average, all houses had two entrance doors, two sliding doors leading to the living room, a sliding/folding door in the dining area and a backyard door. A common opinion among participants was that the increased number of the doors had also reduced the health and safety level, despite that when opened, the doors allow ventilation. House grilles (or iron bars) were thus added for safety reason at the owner's expense. All participants were found to have grilles installed. In addition, the participants highlighted that when doors are opened, their houses were easily accessible by animals, rodent and insects as well as dust, sand, dried leaves and rainwater when blown by the wind. This is made worse for P6 by the inclusion of a green space that could not be used due to the presence of an inspection chamber that released sewage gas and unpleasant odours while also allowing cockroaches to enter the house (Plate 1d). Most of the

"...the rainwater penetrates through windows - two rooms at the back affected... the roof eave is insufficient; the rainwater hits the main door directly. So, the timber door got damaged." (P3)

(a)

"The sliding door is not covered with shade, at the front of the house. The rainwater easily enters the house." (P2)

(b)

"The main door is beside the sliding door. So, if I accidently left my keys in the house, I could just jerk the sliding door's lockset and open the main door easily. So, it shows lack of safety for the design". (P6)

(c)

"Unusable space that maybe designed to encourage planting. But I locked the space to avoid cockroaches from the inspection chamber into the house. The smell of the gas is also bad." (P6)

(d)

"As there is no shade, heat directly enters the house causing the front area become hot." (P2)

(e)

"It is hot, because of many glasses... transparent, not tinted. So, it glares and hot... The kitchen area is very hot due to the direct sunlight through the sliding glass window. The other areas are also very hot during the daytime." (P4)

(f)

"The height and narrow space between the roof and ceiling caused the electrician to work from top of the roof for wiring purpose. That's dangerous." (P5)
** Picture by P5*

(g)

The floor trap cover is bent and cannot be closed, leaving a large gap (P1)

(h)

Plate 1.
Examples of the architectural elements' design deficiencies jeopardising health

doors, therefore, have always been closed and locked. Participants P3 and P4 emphasised that the indoor environment gets hotter when all doors remained closed till evening.

All participants also claimed that the direct sunlight and glare (Plate 1e) via the glass doors and fixed glass panels increased the temperatures of the internal spaces rendering them extremely hot.

4.2 Ceiling

An eye-opening concern raised by P6 draws on the fact that there was no mechanism for the trapped heat towards the top of rooms and towards ceiling level to escape. This was unexpected and explains why heat was conserved within the indoor environment despite the high designed ceilings. Most participants believed high ceilings would generally reduce overall internal temperature levels. Adding to that, interestingly, participant P4 thought that the cavity between the roof and ceiling was too narrow allowing rapid heat transmission from the rooftop into the house. Another worth noting is that participant P5 said the electrician who has worked on many houses in the area affirmed that there was a single layer of aluminium insulation in the cavity. The later raised a notion on the possibility of similarities with *t* "greenhouses" for all the cases.

In general, the ceilings for all houses were high, measuring at least 3.66 m but varies for some houses with slanted roofs reaching up to 4.57 m. A recurrent theme from the interviews was a belief among participants that the excessive number and size of the transparent glass (Plate 1f) increases the heat of indoor environment. Due to the reasons above, all other participants installed mechanical ventilation units such as air-conditioner units, portable fans and exhaust fans.

High ceiling was also associated to maintenance issues and reduced safety that can lead to physical injuries (e.g. the risk of falling when changing light bulb). This was acknowledged when P5 explained that the appointed electrician had to work on the roof top needing them to dismantle the roof tiles (Plate 1g) to install eyeball lights since it was risky to operate in the house where the ceilings were too high, slanted and the cavity space was too narrow for wiring.

4.3 Roof

The roof level was high, steep, pitched and had several types in combination such as shed, gable and flat. Thus, the roof had several valley and rafter connections. All participants experienced roof leaks, including the car porch area. The problem re-occurred even after rectification works.

4.4 Finishes

Apart from the glass materials, which was claimed to be transparent and thin, another reported finishes was the quality of the poorly laminated timber flooring. It became discoloured by the direct exposure to sunshine, in addition to the swelled and bumpy surface due to water penetration. Due to limited funding, half of the participants did not change the floor finishes. Other issues related to finishes, were common, typically, the roof tiles (not of the universal standard and hard to find the replacement), low quality tiles (uneven colour and easily scratched) and poor paint quality (peeled off).

4.5 Sanitary fittings

As for the sanitary fittings, three participants highlighted rusty steel pipes, rusty floor taps as well as bent pipes with large gaps (Plate 1h). Participant P6 observed a house shrew entering the bathroom through the gap. Due to financial restrictions to changing all floor traps, a brick was placed on the bended trap to close the gap. Participant P5 has got all traps changed as to prevent cockroaches from the sewer ingress in the house and to trap hair from clogging the pipes. Other than that, P1 disagreed with the location of the water closet, which restricted smooth movement in the bathroom. P6 stated that the shower position in the bathroom was too close to the sink, disrupting individuals while they were showering. All participants agreed that other fittings were of good quality with no obvious defects. It was observed that most fitting were of good brands too.

4.6 Space

The indoor environment and layout have the least problems even though all houses were of single storey. The layout within the semi-detached and bungalow houses captured in this study was enormous. Only the kitchen was mentioned as being narrow by all participants, prompting most of them to get it extended/renovated.

To this end the results demonstrate concerns that inform the context of the nature and functional health standards of the buildings investigated.

5. Results: condition during movement control order

With regard to restriction due to the COVID-19 pandemic, households were required to spend longer at home than before. Similar issues relating to the level of heat trapped were mentioned by P4 as follows:

> Even though there are many openings in this house, there are often closed to avoid flies and cats entering the house. Therefore, heat trapped in this house longer than it supposed to be.

In all cases, the participants reported increased electricity bills resulting from excessive use of air-conditioning systems due to sustained indoor heat levels. Apart from that, all participants claimed that the heat, glare and direct sunlight also led households to abandon some spaces and/or find a new suitable room in the house, as P5 echoed:

> I have chronic skin problem that requires me to avoid the sun whenever possible. I had to avoid the living room because of the direct sunlight and heat through the glasses. I ended up doing work in my bedroom, which is a lot cooler . . . the rest of the family members are scattered around.

No changes were made to counter the above problems since the first stage of data collection of this research due to limited budget of the participants, except for P2 who integrated sunshade alongside the fixed glass panels and main sliding door. Overall new issues related to architectural elements cropped up during the MCO (albeit minimum). P4 experienced bad odour from the toilet and felt disappointed with the poor air circulation. All participants acknowledged that their homes were spacious enough to prevent such odour retention, as P1 stated that:

> The layout of house allows movement; it does not make the situation bored as there are many areas to move around. I have no problem working online because there are many spaces I can choose.

Two participants pointed out that the interior colour made the house peaceful. Participants exhibited self-belonging, as P2 stressed:

> The overall design of the house is suitable for our family. WFH/home schooling builds a strong relationship among our family/positive relationship . . . Learning/work from home is fun and exciting. . ..

In addition, P4 added that:

> Even though the above problems occur in this house, it is still comfortable to live in for some reasons. It still can fit six members of the house. I am still grateful to own this house.

Furthermore, participants, on the whole, associated space with the external compound, which were also spacious and allowed activities such as gardening, swimming and skateboarding during the lockdown periods.

6. Discussion

The study was intended to identify the determinants and relation between healthy homes and design deficiencies in the context of architectural elements. On the positive remarks, it appears ideal to stay at home during the pandemic when the house is spacious. Having space allows indoor and outdoor activities to be carried out within the house area. It offers households the ability to enjoy more privacy. Furthermore, single storey houses eliminate the issues related to staircase and isolation between two floors. Space was least problematic in this study but the impact of having enough space was noted to be vital to provide tranquillity, peace and harmony in the house and among the members of the household. While individuals felt that they were part of their homes, it does not indicate that the houses were completely healthy. The study confirmed previous findings such as excessive heat, glare, narrow spaces and height among characteristics that can impact safety and health. This is echoed in research by Connellan *et al.* (2013), Ergan *et al.* (2018) and Zuurbier *et al.* (2021).

From the results, it is revealed that the households did not realise that the continuous use of damaged laminated timber flooring impacted their health, as supported by Wheeler *et al.* (2016). This is because not only did the wood bonding adhesives discharge toxins in the form of volatile organic compounds (VOCs), the material may also contains other substances such as melamine-formaldehyde and isocyanates, which have health effects as explained by Frihart and Hunt (2021). Another finding was that the use of transparent and thin glass materials for the doors and fixed panels, without taking into account the effect of heat transmission and glare, disrupts the comfort and health of the households within increase temperature zones. Cuce *et al.* (2014) conducted simulations of buildings with an integrated glass and concluded that while glazed buildings have become a wide reaching trend for all climates, their performance still needs to be improved in order to satisfy climate appropriate energy efficiency standards.

Bringing the findings together, a possible explanation of prolonged heat for the cases is that the glass allows direct sunlight, which impacts the indoor environment as it traps heat that ultimately increases indoor temperatures. As heat rises, it reaches the top of the apex of the designed ceiling, which potentially helps in reducing the indoor temperature levels. However, there was no natural or artificial vents designed for the heat to escape even though these buildings were built in a hot climatic region such as the country of study. Trapped heat within the indoor environment is a severe health risk that can lead to death, particularly for those with medical conditions, confined to their home for an extended period of time and do not have access to air-conditioning systems (Semenza *et al.*, 1996). The use of air condition units remains significant due to the hot climate conditions. An unforeseen finding was that the heat is further trapped because the aluminium sheets laid in the roof cavity prevents heat loss. This is contrary to the belief that the heat from the sun is transmitted rapidly through the narrow roof cavity into the room. The overall phenomenon is as illustrated in Plate 2, with significant glass materials that have features of a greenhouse. With the cumulation of heat from this effect it can be harmful to the health of the households due to the increased level of heat trapped (due to the glass materials).

The findings show that the designs of the houses circulate heat, and there is also a possibility of polluted indoor air especially when there is a lack of natural ventilation. Indoor air pollution can be caused by the finishes such as the laminated timber floor, cleaning chemicals or gases from the kitchen. Excessive usage of air-conditioning to keep houses cool can reduce the risk of health from getting worse or death (Semenza *et al.*, 1996). However,

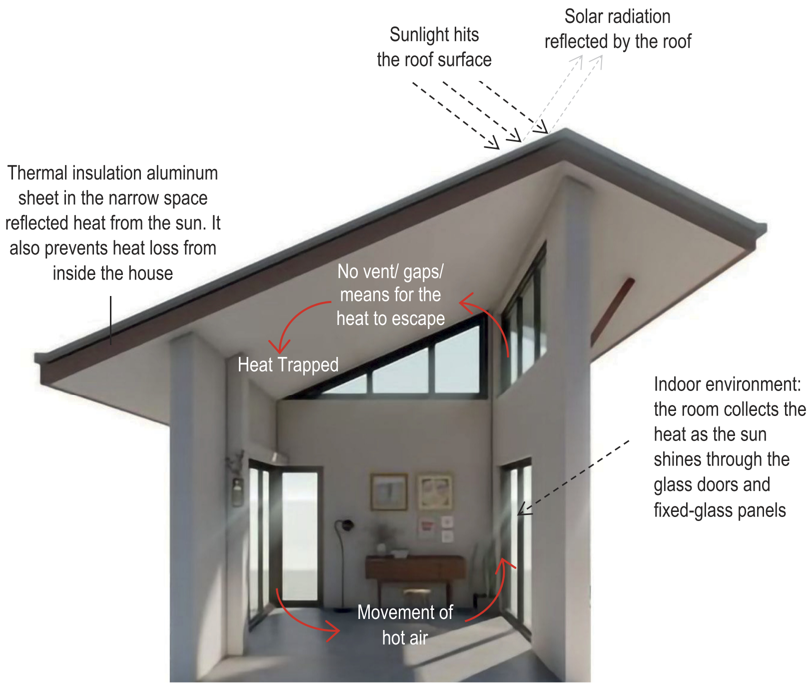

Plate 2. Illustration of the P5 living room: undesired heat circulation in a hot country

without efficient filters, air-conditioning will not help in addressing polluted air, rather would increase the blood pressure, systemic inflammation and imposed risks to cardiovascular diseases (Chuang *et al.*, 2017). There is no doubt that laminated timber flooring and glazing offer aesthetic and elegant values to the design, which are renowned in Malaysian, especially in new residences. However, deciding the use of these materials in hot tropical countries without considering its adverse impact to health is not ethical. Thus, designers and developers need to focus on the health of people rather than adopting modern designs from cold and temperate countries that can be unsuitable for tropical climates. The results presented a significant overdesign with too many doors without adequate quality and suitable (to the context climate) material considerations.

Another unanticipated finding was that the quality of lock kits and the number of doors impact the concern of the households about their health and safety. This finding was also reported by Azani *et al.* (2020) who stated that in Malaysia, the improper design of doors, windows and the poor quality of lock kits are among the reasons that result in people installing grilles for safety, despite the disadvantages of households caught in fire emergency. This could lead to serious injuries and health problems, as well as death (Azani *et al.*, 2020). This finding may help researcher to understand that people are used to and continue to accept the same low quality locks on doors or lock kits unless the designers and developers pay more attention to this issue. Nevertheless, there has been very little studies about the doors, windows, their lock kits and accessories.

The design of the ceiling and roof imposes risk of working at a high and steep level especially for maintenance purposes which corroborate with Wardle and Duncan (2017) and "WHO Housing and health guidelines" (2018). What is unexpected, albeit the roofs were steep, there were frequent leaks. One plausible factor is poor design of roof connections that disabled proper flashing installation and prevented suitable watertight barrier when the pressure of rainwater at certain points is high. However, this general proposition needs further detail investigations. The overall design of the roof did not accommodate the weather and irradiance effect due to the orientation of the building to the sun, linked to the height of the wall. This resulted in insufficient and ineffective eaves design, to prevent water ingress and direct sunlight into the house. The roof of buildings is one of the primary defences against outside elements. The finding indicates that there was no improvement made by the developer in tackling the water penetration issue since Phase 1 of development, which further strengthens the idea that weather conditions was not entirely considered by the designer. A simple measure to prevent water penetration such as door seals or weatherstrip may have been introduced to tackle the issue, however, they were not considered by the designer.

Apart from the above-mentioned elements, our analysis provides evidence that sanitary fittings, mainly the floor traps, have been acknowledged to trap surface dirt and prevent entry of rodents and insects, thereby preventing the spread of diseases. Furthermore, the location of fittings is important to avoid injuries. However, there have been less discussions about sanitary fittings in the context of built environment and healthy homes literature.

In essence, the findings presented in this study suggest that the common design deficiencies must be addressed by the designers, developers and local authorities to provide healthy housing for the future. Although the building code (Uniform Building By-Law) outlined the minimal standards for architectural, structural and fire requirements, they do not deal with the extent of how homes should be designed. In other words, the location of architectural elements, as well as their quantity and size, are entirely up to the developers' and architects' discretion, as long as they comply with the Uniform Building By-Law. According to Krieger and Higgins (2002), building codes cover only a subset of the circumstances that determine housing quality, but they do not address the maintenance or rectification of deficient situations. Vaughan and Turner (2013, p. 2) suggested that "State and local policymakers should also consider: the cost to public health and safety from design flaws or improper installation; the unnecessary cost to home owners, businesses and taxpayers from buildings wasting energy and water... ." The effort towards healthy homes needed the integrated involvement of the public health departments to offer consultations on the affordability of healthy housing for all ages including senior citizens (Krieger and Higgins, 2002). This means that, in addition to architects and developers, local authorities can make empathic decisions about preserving, improving and creating ethical designs while adhering to building codes in order to promote the healthy growth and development of society.

7. Conclusions

Homes should offer protection, allow privacy and maintain external security particularly in the event of pandemics. However, the houses studied in this research have indicated that homes may not be a completely healthy or a safe place, despite their modern design. The effects of the architectural elements on health can be apparent. For example, spacious houses have shown to affect the comfort, behaviour and positive emotions of the households. Meanwhile, overly designed glass doors and fixed glass panels, high and steep pitched ceiling/roof, low-quality key lock sets and accessories, unsuitable sanitary fittings as well as unhealthy finishes can have negative influence on the households. Due to financial restrictions, repairs or modifications remain the last option for the owners to deal with design deficiencies. This implies that their health and safety remain jeopardised. Unfortunately, when the owners modify, they often overlook new hazards that might have a severe influence on the health of the household (such as the use of home grilles and ineffective filtered air-conditioners).

The findings call for further studies and actions by the local councils and existing housing bodies to adopt the minimum requirements and strategies of healthy homes design elements that affect common health issues. To this end, the knowledge presented in this paper has enabled the identification of key healthy homes elements that traverse with architectural design deficiencies especially in the building types investigated. Among essential safety homes strategies that can be included for new developments (and existing houses) are the use of tinted/double glazed facets to prevent glare and heat, quality door lock sets to ensure safety, ventilation fans or bricks that allows hot air exit, weather strip to prevent water penetration and mosquito net to avoid the ingress of insects and rodents. However, the ideal design elements that encourage health, enhances safety and prevent spread of diseases for tropical climate is inconclusive and requires further exploration or simulations. Many deficiencies may be avoided by knowing the aspects of healthy housing and by the construction players' ethical concern. Ethical design for health equity is not costly to develop. In particular, designers and developers should learn from deficiencies that produce harmful circumstances.

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