Furniture layout in residences- the role of thermal comfort

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1. Abstract

People spend most of their active time at home in living rooms. The furniture in living areas is designed based on the multiple activities generally performed in a living space. The objective of the study was to assess the factors influencing the arrangement of furniture layout in the perspective of occupant behaviour research. The behaviour of arrangement of furniture was evaluated in terms of Physical Environmental Triggers (PET), Physical Environmental Factors (PEF), Psychological Factors (PF), Social Factors (SF), Physiological Factors (PHF) and Non-Adaptive Triggers (NAT). The study developed an instrument measuring these factors along with the respondents' satisfaction with the current layout. The collected data was analyzed with Confirmatory Factor Analysis (CFA) and Structural Equation Modelling (SEM). Construct validity of the model has been established by estimating the convergent validity and discriminant validity. The absolute fit indices satisfy the recommended values and indicates that the proposed model has an acceptable fit. Contextual factors which comprises Physical Environmental Factors, Psychological Factors, Social Factors, and Physiological Factors, is identified as a major factor affecting the behaviour. This study will give an insight for architects regarding the perceptions of an occupant which results in greater satisfaction with space with energy implications of the layouts.

Keywords - Furniture Layout, Residences, Satisfaction, Thermal Comfort, Energy Efficiency

2. Introduction

Residences in India primarily consist of a living room, bedroom, kitchen, dining and restrooms. However, a family spends most of the productive time in the house in living space, excluding sleep time [1]. A family spends time in the living area by chatting, watching television, reading books or newspapers, playing and welcoming the occasional guests. The furniture in the space is arranged in such a way to cater to all the mentioned activities. However, the decision of furniture layout may be limited by physical characteristics like the position of doors and windows, location of the ceiling fan, building orientation, extent of the space and layout etc. A layout of the furniture may demand a compromise on certain needs. For example, the furniture arrangement of a type may enhance the spaciousness of the area when the furniture is aligned along the wall, while compromising on air movement from the windows or ceiling fans. The prioritization of different needs results in a specific layout inside each residence. Thermal comfort and need for air movement to achieve thermal comfort is an essential criterion in the decision of a layout in warm and humid climates [2]. The choice of furniture type and material is based on the flexibility for spatial adaptations. In summer, the layout tends to be fan-centric since the primary need is the availability of air movement for thermal comfort. Whereas, in winter, other preferences and needs play a dominant role and results in a variety of furniture layouts in the same space.

While it is generally understood that occupants may change their posture or relocate within a room to improve comfort, no experimental or in-situ results were found in the literature [3]. However, there are many studies which evaluate the airflow characteristics and thermal comfort in a space with the presence of furniture [2,4–11]. Furniture layout is identified as an essential factor determining the indoor air quality, airflow and temperature fields and ventilation efficiency [6,7]. The presence of furniture in a room creates a complicated airflow recirculation and higher air velocities near the furniture edges along with a non-uniform distribution of air currents [4,5]. It was identified that a partition wall plays a significant role in maintaining indoor temperature distribution and airflow characteristics. A unit with lower partition wall height, a higher distance of the partition wall from the window and lesser distance between bed and window is found to provide maximum airflow within the breathing zone [8]. The parameters considered by the subjects in their respective arrangements were visual comfort, view, sunshine, control, privacy, concentration, centralization, relaxation, lighting, circulation, diversity, overheat and warmth.

This study intends to assess the factors influencing the arrangement of furniture layout in a residential living room in the perspective of occupant behaviour research. Occupant behaviour can be defined as proposed by [12] as "a human being's unconscious and conscious actions to control the physical parameters of the surrounding built environment based on the comparison of the perceived environment to the sum of past experiences". The factors influencing occupant behaviour was initially classified as internal factors and external factors by Schweiker and Shukuya [13] where internal factors include preferences, attitude, cultural background etc. and external factors include building and environment-related features. Later Fabi et al.[14] presented a refined classification of drivers of occupant behaviour into five categories: physical, environmental, contextual, psychological, physiological and social factors. A better explanation of the terms 'internal factors' and 'external factors' were proposed by Polinder et al. [15]. Internal driving forces evolved from interactions between biological and psychological aspects, and these are investigated in the domains of social science, biology and economics. External driving forces comprise of building, physical environment and time, which stimulates a reaction in an individual.

Recent research by Wagner et al. [3] categorized the drivers of occupant behaviour as adaptive triggers, nonadaptive triggers and contextual factors as given in Table 1. Contextual factors are considered as the moderators of triggers and behaviour. Adaptive triggers include physical environment triggers and physiological triggers. Physical environmental triggers correspond to the physical properties of the environment, which, when varied, creates stimulation in the occupant. Non-adaptive triggers are the factors that are independent of physical environmental triggers. Contextual factors are grouped into four categories- physical environmental factors, psychological factors, social factors and physiological factors, based on earlier research [14]. Contextual factors remain unchanged for a period, unlike the physical environmental and physiological triggers.
The objectives of the study are: (a) To study the factors influencing occupant behaviour in the context of arranging the furniture layout in a living room, and (b) To evaluate whether all the measures fit the recommended value to indicate a good fit of the structural model for the collected data.

Table 1: Potential influencing factors driving occupants' behaviour in a building [3]

Trigger		Factors
Adaptive Triggers	Physical Environmental Triggers	Indoor air & mean radiant temperature, Indoor air humidity, Indoor air velocity, Contaminants, concentration of air, Outdoor air temperature & humidity, Solar radiation, Wind speed, Rainfall, Illuminance, Luminance, Colour temperature, Daylight factor, Sound level
	Physiological Triggers	Body temperature, Skin temperature, Skin wetness
Contextual Factors	Physical Environmental Factors	Season, Duration of presence in the room, Frequency, Building quality, Building use, availability & accessibility of controls, operable devices, State of other devices, Clothing insulation level, Interior design and furniture, Ease & convenience of using building system interfaces (light switches), Economics of energy, Presence of feedback systems for energy, View to outside
	Psychological Factors	Knowledge, expectations, Preference, acceptability, Perception, Needs about comfort, health, safety, Awareness, Mood, Habit, lifestyle, View/interaction with outdoors, Previous activities
	Social Factors	Group interaction, Presence of multiple occupants (e.g. Privacy), Group composition, Social constraints (e.g. dress code), Social status, Education, Country of origin, Safety, Ownership of the building
	Physiological Factors	Age, sex, weight, Body dimensions, Health state, Ethnic group
Non-Adaptive Triggers		Time of the day, Scheduled activity

3. Methods

The recent classification by [3] gives a better understanding of the factors on occupant behaviour. The seven factors proposed by (Wagner et al., 2018) were adopted to develop the questionnaire measuring the perceptions of occupants while arranging the furniture in the living space of a residence. The behaviour of arranging furniture was measured in terms of satisfaction with the current layout. Satisfaction can be seen to serve either as a criterion for evaluating the quality of the residential environment (by measuring the effect of perceptions and assessments of the objective environment upon satisfaction) or as a predictor of behaviour [16] which is relevant in the current study. A five-point scale was used to indicate the agreement or disagreement (Strongly disagree, Disagree, Neither agree nor disagree, Agree, Strongly agree) towards the prepared statements under each factor. The respondents were also asked to rate their level of satisfaction with the current layout on a five-point scale (Very satisfied, Satisfied, Neither satisfied nor dissatisfied, Dissatisfied, Very Dissatisfied). The questionnaires were circulated through a web-based platform to ensure a wider reach into the housing and demographic categories. Data was collected from 305 occupants conforming to the recommendation by Hair et al.[17], which is a sample size which is ten times the number of statements. Collected data were analyzed with the software SPSS 23 and AMOS 23. No missing data was observed as it was mandatory to answer all questions before submitting in the online platform.

4. Results

Descriptive statistics of the profile of the respondents is given in Table 2. Respondents living in apartments (56.4%), as well as individual houses (43.6%), participated in the study. 66.2% of the respondents belonged to a family having four or more members, while only 1.6% of respondents stayed alone. The type of furniture used in their living rooms are lightweight which is easily moveable (24.3%), heavy furniture like a sofa which is difficult to move (33.4%) and a combination of light and heavy furniture (42.4%). The details on the usage of ceiling fans, desk fans/wall fans and air-conditioners are also given in Table 2.

Table 2. Descriptive statistics of the profile of the respondents

Item	Type	Number of respondents	Percentage (%)
House type	Apartment	133	43.6
	Individual house	172	56.4
Family size (Number)	1	5	1.6
	2-3	98	32.1
	Four or more	202	66.2
Furniture	Lightweight	74	24.3
	Heavy	102	33.4
	Both	129	42.4
Presence of ceiling fans (Number)	0	34	11.1
	1	185	60.7
	2	86	28.2
Presence of desk fan/ wall fan (Number)	0	234	76.7
	1	55	18.0
	2	16	5.2
Presence of Air conditioner (Number)	0	261	85.6
	1	35	11.5
	2	9	3.0

Cronbach's alpha coefficient, which is the most widely accepted measure [17] to evaluate the reliability and consistency of the survey instrument, is estimated as given Table 3. Cronbach's alpha value above 0.7 is considered to be ideal[17]. In this case, Cronbach's alpha value above 0.7 is observed for all factors, and an overall Cronbach's alpha value of 0.758 attained, indicating a high level of internal consistency for the scale. Further tests on validity were assessed in terms of convergent validity and discriminant validity at a later stage.

Table 3: Reliability analysis for the survey instrument

Factor	Number of statements	Cronbach's alpha
Physical Environmental Triggers (PET)	5	0.715
Physical Environmental Factor (PEF)	6	0.719
Psychological Factors (PF)	9	0.702
Social Factors (SF)	3	0.826
Physiological Factors (PHF)	3	0.823
Non-Adaptive Triggers (NAT)	3	0.760
Overall reliability analysis	30	0.758

Structural equation modelling is performed to assess the suitability of the model based on the data collected. Confirmatory factor analysis or measurement model was evaluated first to test the reliability and validity of the survey questionnaire as recommended by [18]. Confirmatory factor analysis was conducted using AMOS 23 to evaluate the significance of the statements. 16 out of 30 statements were found to be significant at 1% level (p-value <0.001) and having factor loading greater than 0.5[19]. Further analysis is limited to these 16 statements as these statements measure the construct.

4.1 Structural equation modelling: Model fit assessment

Structural equation modelling assesses whether the data fit into the proposed theoretical model. Model fit is evaluated in Table 4 and the acceptability of the structural model is supported by the recommended values of the common goodness of fit indices. Null hypothesis and alternative hypothesis are framed to test the fit of this structural model.

Table 4. Model fit Indices

Fit indices	Results	Recommended values
Chi-square	78.457 (0.000) DF- 84	
p-value	0.650	>0.05 [18]
Chi-square/ Degrees of freedom	0.934	≤5.00 [17]
Goodness of Fit Index (GFI)	0.970	>0.90 [20]
Adjusted Goodness of Fit Index (AGFI)	0.951	>0.90 [20]
Comparative Fit Index (CFI)	1.000	>0.90 [21]
Normated Fit Index (NFI)	0.952	≥0.90 [21]
Incremental Fit Index (IFI)	1.004	Approaches 1
Tucker Lewis Index (TLI) or Non-Normed Fit Index (NNFI).	1.00	≥0.90 [21]
Root Mean square Residuals (RMR)	0.048	<0.08 [18]
Root Mean Square Error of Approximation (RMSEA)	0.000	<0.08 [18]

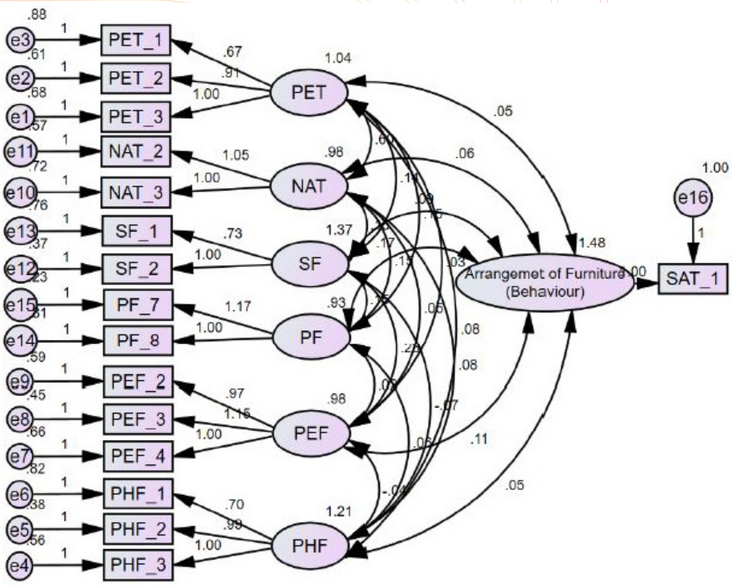

Figure 1: Structural model

Hypothesis

Null Hypothesis (H0): The hypothesized model has a good fit.
Alternate Hypothesis (H1): The hypothesized model does not have a good fit.
The test for our null hypothesis (H0) as shown in the figure resulted in a chi-square value of 78.457 with 84 degrees of freedom with a probability of 0.650 (p-value >0.05). These results suggest a good fit of the model. Table 5 shows the unstandardized coefficients and associated test statistics. Unstandardized regression coefficient indicates the amount of change in the dependent variable created by a one-unit change in the predicting variable. CR stands for Critical Ratio, which is obtained by dividing the estimate with the Standard Error (SE). For every single unit change in PET2, PET would increase by 1.366 units.

Table 5: Regression Weights: (Group number 1 - Default model)

Statement		Factor	Estimate	S.E.	C.R.	P
PET_1 (Fresh air and daylight)	<---	PET	1.000			
PET_2 (Air from ceiling fan)	<---	PET	1.366	.154	8.865	<0.001
PET_3 (Air from the window)	<---	PET	1.497	.169	8.881	<0.001
PHF_1 (Heavy furniture)	<---	PHF	1.000			
PHF_2 (Comfortable for old aged)	<---	PHF	1.403	.126	11.098	<0.001
PHF_3 (Safe for toddlers)	<---	PHF	1.419	.127	11.204	<0.001
NAT_3 (Space for multiple activities)	<---	NAT	1.000			
NAT_2 (Daylight for reading)	<---	NAT	1.049	.126	8.352	<0.001
SF_2 (Aesthetically pleasing)	<---	SF	1.368	.360	3.802	<0.001
SF_1 (Spaciousness to welcome guests)	<---	SF	1.000			
PF_8 (Safety concerns near a window)	<---	PF	.858	.228	3.758	<0.001
PF_7 (Spaciousness)	<---	PF	1.000			
PEF_3 (Fan and light controls)	<---	PEF	1.189	.087	13.707	<0.001
PEF_2 (Building features)	<---	PEF	1.000			
PEF_4 (Not blocking circulation space)	<---	PEF	1.033	.078	13.181	<0.001
SAT_1 (Satisfaction with the current layout)	<---	Furniture	1.217	.083	14.717	<0.001

Table 6 presents the standardized weights for the model. Standardized estimates evaluate the relative contributions of each predictor variable on each outcome variable. Figure 1 shows the structural model with seven factors. From Figure 1, it is evident that occupants attach more value with the satisfaction on the layout while all the factors influence the satisfaction with the layout.

Table 6: Standardized Regression Weights: (Group number 1 - Default model)

			Estimate
PET_1	<---	PET	0.588
PET_2	<---	PET	0.766
PET_3	<---	PET	0.778
PHF_1	<---	PHF	0.650
PHF_2	<---	PHF	0.869
PHF_3	<---	PHF	0.827
NAT_3	<---	NAT	0.758
NAT_2	<---	NAT	0.809
SF_2	<---	SF	0.886
SF_1	<---	SF	0.699
PF_8	<---	PF	0.731
PF_7	<---	PF	0.919
PEF_3	<---	PEF	0.862
PEF_2	<---	PEF	0.782
PEF_4	<---	PEF	0.774
SAT_1	<---	Furniture	0.773

4.2 Construct validity of the measurement model

The validity of the construct is assessed to ensure that the measurement scale accurately represents the concept of interest. The most accepted measures of validity are convergent validity, discriminant validity and nomological validity [21]. Convergent validity establishes that the scale is correlated with other known measures of the concept. Discriminant validity confirms that the scale is adequately different from other similar concepts to be distinct, and nomological validity verifies whether the scale demonstrates the relationships shown to exist based on theory or prior research.

Convergent validity is established by evaluating the factor loadings, Average Variance Extracted (AVE) values and Construct Reliability (CR) values. AVE for each construct is computed as the sum of all squared standardized factor loading divided by the number of items. AVE is recommended above 0.5 [19] to suggest adequate convergent validity. An AVE value of less than 0.5 points out that on average, there is more error remaining in the items than the variance explained by the latent factor structure imposed on the measure. AVE measure should be computed for each latent construct in a measurement model as given in Table 7. It is found that the least AVE value obtained is 0.513 and all the constructs (PET, PHF, NAT, SF, PF, PEF and Furniture arrangement) have attained an AVE above 0.5. Construct Reliability (CR) value of 0.7 or higher suggests good reliability [19]. Reliability between 0.6 and 0.7 may be acceptable, provided that other indicators of a model's construct validity are good. High construct reliability indicates that all measures consistently represent the same latent construct. The calculated CR values for each construct is presented in Table 7.

			FL	Item reliability (IR)	Delta	AVE	Sum of FL	Sum of delta	CR
PET_1	<---	PET	0.588	0.346	0.654				
PET_2	<---	PET	0.766	0.587	0.413				
PET_3	<---	PET	0.778	0.605	0.395	0.513	2.132	1.462	0.76
PHF_1	<---	PHF	0.650	0.423	0.578				
PHF_2	<---	PHF	0.869	0.755	0.245				
PHF_3	<---	PHF	0.827	0.684	0.316	0.621	2.346	1.138	0.83
NAT_3	<---	NAT	0.758	0.575	0.425				
NAT_2	<---	NAT	0.809	0.654	0.346	0.615	1.567	0.771	0.76
SF_2	<---	SF	0.886	0.785	0.215				
SF_1	<---	SF	0.699	0.489	0.511	0.637	1.585	0.726	0.78
PF_8	<---	PF	0.731	0.534	0.466				
PF_7	<---	PF	0.919	0.845	0.155	0.689	1.650	0.621	0.81
PEF_3	<---	PEF	0.862	0.743	0.257				
PEF_2	<---	PEF	0.782	0.612	0.388				
PEF_4	<---	PEF	0.774	0.599	0.401	0.651	2.418	1.046	0.85
SAT_1	<---	Furniture	0.773	0.598	0.402	0.598	0.773	0.402	0.60

Table 7: Average Variance Extracted and Composite Reliability

The initial results support the convergent validity of the measurement model. Although two loading estimates are below 0.7, one of these is just below the 0.7 and do not appear to be significantly harming model fit or internal consistency. The average variance extracted (AVE) estimates all exceed 0.5 and the construct reliability estimates all exceed 0.7 except one case where it is 0.6 but acceptable, provided that other indicators of a model's construct validity are good [19]. Besides, the model fits relatively well based on the model fit indices. Therefore, all the indicator items are retained, and adequate evidence of convergent validity is provided. Discriminant validity measures the extent to which a construct is truly distinct from others. Discriminant validity is proved when the AVE estimates are higher than the square of the correlation between the two factors. All AVE estimates are greater than the corresponding inter-construct squared correlation estimates in Table 8. This indicates the measured variables have more in common with the construct they are associated with than they do with the other constructs.

Factors	AVE	Squared Inter-construct Correlation						
		PET	NAT	PEF	PF	SF	PHF	SATI
PET	0.513	-	0.356	0.000	0.021	0.014	0.004	0.002
NAT	0.615	0.356	-	0.001	0.028	0.016	0.005	0.003
PEF	0.651	0.000	0.001	-	0.000	0.039	0.001	0.012
PF	0.689	0.021	0.028	0.000	-	0.016	0.003	0.019
SF	0.637	0.014	0.016	0.039	0.016	-	0.003	0.004
PHF	0.621	0.004	0.005	0.001	0.003	0.003	-	0.002
SATI	0.598	0.002	0.003	0.012	0.019	0.004	0.002	-

Table 8: Discriminant Validity

5. Discussion

Previous research on the occupant behaviour and triggers focused on the influence of occupant behaviour on energy consumption in a building [3,22,23]. This study follows a different approach, where the triggers and factors concerning the behaviour of arranging furniture layout of a living room is explored with respect to the satisfaction with the current layout. Contextual factors which comprises of Physical Environmental Factors (CR-0.85, AVE-0.651), Psychological Factors (CR-0.81, AVE-0.689), Social Factors (CR-0.78, AVE-0.637), and Physiological Factors (CR-0.83, AVE-0.621), is identified as a major factor affecting the behaviour of occupants as pointed out by [24,25]. These results are agreeable with studies by [3] which also states contextual factors as the moderator of triggers and behaviour. Within contextual factors, Physical Environmental Factors (CR-0.85, AVE-0.651) is identified to be having a significant influence on the arrangement of furniture. Even though the thermal comfort and need for air movement is an essential criterion in the decision of a layout in warm and humid climates [2], the current study proves that several other factors categorized under Contextual factors influence the arrangement of furniture in a living room to a greater extent than Physical Environmental Triggers (Indoor air & mean radiant temperature, Indoor air humidity, Indoor air velocity etc.). Inferences about the relationship between a building and its occupants can inform improvements to future building designs with regards to energy and comfort performance [3]. People prefer adopting mechanical ventilation strategies like AC to alleviate the thermal discomfort irrespective of their ideologies or situational factors [26]. In the current scenario of Covid-19 pandemic, people spend more time indoors owing to the work from home situation and the layout of the rooms is modified to include a working space/ study space for each of the family members [10]. Occupants prefer to have ACs for the 'positive human energy' by being in good physical condition and not struggling while working from home [26].

6. Conclusion

The study aimed to conduct an empirical analysis of the factors or perceptions influencing the arrangement of furniture layout inside the living room of a residence. The behaviour of arrangement of furniture was assessed in terms of Physical Environmental Triggers (PET), Physical Environmental Factor (PEF), Psychological Factors (PF), Social Factors (SF), Physiological Factors (PHF) and Non-Adaptive Triggers (NAT) using structural equation modelling. The study developed an instrument measuring these factors along with the respondents' satisfaction with the current layout. The findings show that Cronbach's alpha for all the factors is above 0.7, which indicates a high level of internal consistency for the scale. Based on the confirmatory factor analysis, it can be concluded that the presented scale in this study shows adequate fit into the collected data. Model validity is established and it can be concluded that the seven-factor model shown in Figure 1 represents the behaviour of arranging furniture layout, thereby supporting the model fit and accepting the structural model. Contextual factors which comprise Physical Environmental Factors, Psychological Factors, Social Factors, and Physiological Factors, is identified as a major factor affecting the behaviour of occupants. This study will give an insight for architects and interior designers regarding the perceptions, or the factors considered by an occupant which results in greater satisfaction with space. This can be applicable while proposing the layout of a new project or a renovation project. This study focuses on the living rooms of a residence. Hence, it may not be generalized for any residential space as the activities and purpose of space may vary, which is not included in the current study. Another limitation of the study points to unavailability of more details for a closer analysis of the situations as it was a web-based survey. Further research is being carried out by incorporating on-site observations and measurements in different settings.

7. Acknowledgements

This work was supported in part by the Department of Science and Technology, Ministry of Science and Technology, Government of India through the Indo -UK project- Community-Scale Energy Demand Reduction in India (CEDRI) under Grant DST/TMD/UK-BEE/2017/20.

8. References

[1] Khajehzadeh I, B. Vale, How do people use large houses, in: Living Learn. Res. a Better Built Environ. Proceeding 49th Int. Conf. Archit. Sci. Assoc., 2015: pp. 153–162.

[2] S. Hawendi, S. Gao, A.Q. Ahmed, Effect of heat loads and furniture on the thermal comfort of an isolated family house under a naturally ventilated environment, Int. J. Vent. 0 (2019) 1–26. https://doi.org/10.1080/14733315.2019.1600815.

[3] A. Wagner, W. O'Brien, B. Dong, Exploring Occupant Behavior in Buildings, Springer, 2018. https://doi.org/10.1007/978-3-319-61464-9.

[4] K. Horikiri, Y. Yao, J. Yao, Numerical optimisation of thermal comfort improvement for indoor environment with occupants and furniture, Energy Build. 88 (2015) 303–315. https://doi.org/10.1016/j.enbuild.2014.12.015.

[5] D.D. Sabie, A.-G. Ghiaus, Influence of furniture arrangement on airflow distribution in open concept passive houses, E3S Web Conf. 85 (2019) 01010. https://doi.org/10.1051/e3sconf/20198501010.

[6] R. Zhuang, X. Li, J. Tu, CFD study of the effects of furniture layout on indoor air quality under typical office ventilation schemes, Build. Simul. 7 (2014) 263–275. https://doi.org/10.1007/s12273-013-0144-5.

[7] S. Hormigos-Jimenez, M.Á. Padilla-Marcos, A. Meiss, R.A. Gonzalez-Lezcano, J. Feijó-Muñoz, Assessment of the ventilation efficiency in the breathing zone during sleep through computational fluid dynamics techniques, J. Build. Phys. 42 (2019) 458–483. https://doi.org/10.1177/1744259118771314.

[8] A. Sarkar, R. Bardhan, Optimizing Interior Layout for Effective Experiential Indoor Environmental Quality in Low- income Tenement Unit : A Case of Mumbai , India, in: Build. Simul. Optim. Conf., 2018: pp. 11–12.

[9] K. Cheong, E. Djunaedy, K. Tham, S. Sekhar, N. Wong, M. Ullah, Influence of furniture layout and ventilation design on air quality and thermal comfort, in: Indoor Air 2002, 9th Int. Conf. Indoor Air Qual. Clim., 2002: pp. 302–307.

[10] T.K. Jayasree, B.S. Jinshah, T. Srinivas, The effect of opening windows on the airflow distribution inside naturally ventilated residential bedrooms with ceiling fans, Build. Serv. Eng. Res. Technol. 1 (2021) 23– 39. https://doi.org/10.1177/01436244211024084.

[11] S. Tadepalli, T. Jayasree, L. Visakha V, S. Chelliah, Influence of ceiling fan induced non-uniform thermal environment on thermal comfort and spatial adaptation in living room seat layout, Build. Environ. 205 (2021) 108232. https://doi.org/10.1016/J.BUILDENV.2021.108232.

[12] M. Schweiker, Occupant behaviour and the related reference levels for and cooling, Tokyo City University, 2010.

[13] M. Schweiker, M. Shukuya, Comparison of theoretical and statistical models of air-conditioning-unit usage behaviour in a residential setting under Japanese climatic conditions, Build. Environ. 44 (2009) 2137–2149. https://doi.org/10.1016/j.buildenv.2009.03.004.

[14] V. Fabi, R.V. Andersen, S. Corgnati, B.W. Olesen, Occupants' window opening behaviour: A literature review of factors influencing occupant behaviour and models, Build. Environ. 58 (2012) 188–198. https://doi.org/10.1016/j.buildenv.2012.07.009.

[15] H. Polinder, M. Schweiker, A. Van Der Aa, K. Schakib-ekbatan, V. Fabi, R. Andersen, N. Morishita, C. Wang, S. Corgnati, P. Heiselberg, B. Olesen, Occupant behavior and modeling, 2013.

[16] S. Weidemann, J.R. Anderson, A Conceptual Framework for Residential Satisfaction, Home Environ. (1985) 153–182. https://doi.org/10.1007/978-1-4899-2266-3_7.

[17] J. Hair, W.C.W.C. Black, B.J. Babin, R.E. Anderson, J. Joseph F. Hair, W.C.W.C. Black, B.J. Babin, R.E.
Anderson, Multivariate Data Analysis, Pearson New International Edition, 2017. https://doi.org/10.1002/9781118895238.ch8.

[18] T.A. Brown, Confirmatory Factor Analysis for Applied Research, Guilford publications, 2015. https://doi.org/10.1198/tas.2008.s98.

[19] J. Joseph F. Hair, W.C. Black, B.J. Babin, R.E. Anderson, Multivariate Data Analysis, 2017. https://doi.org/10.1002/9781118895238.ch8.

[20] D. Hooper, J. Coughlan, M.R. Mullen, J. Mullen, D. Hooper, J. Coughlan, M.R. Mullen, Structural Equation Modelling : Guidelines for Determining Model Fit Structural equation modelling : guidelines for determining model fit, Electron. J. Bus. Res. Methods. 6 (2008) 53–60. www.ejbrm.com.

[21] D. Harrington, Confirmatory Factor Analysis, Oxford University Press, 2009. https://doi.org/10.1017/CBO9781107415324.004.

[22] V. Fabi, R.V. Andersen, S.P. Corgnati, B.W. Olesen, A methodology for modelling energy-related human behaviour: Application to window opening behaviour in residential buildings, Build. Simul. 6 (2013) 415– 427. https://doi.org/10.1007/s12273-013-0119-6.

[23] D. Yan, W. O'brien, T. Hong, X. Feng, H.B. Gunay, F. Tahmasebi, A. Mahdavi, W. O'Brien, T. Hong, X. Feng, H. Burak Gunay, F. Tahmasebi, A. Mahdavi, Occupant behavior modeling for building performance simulation: Current state and future challenges, Energy Build. 107 (2015) 264–278. https://doi.org/10.1016/j.enbuild.2015.08.032.

[24] W. O'Brien, H.B. Gunay, The contextual factors contributing to occupants' adaptive comfort behaviors in offices - A review and proposed modeling framework, Build. Environ. 77 (2014) 77–87. https://doi.org/10.1016/j.buildenv.2014.03.024.

[25] F. Stazi, F. Naspi, M. D'Orazio, A literature review on driving factors and contextual events influencing occupants' behaviours in buildings, Build. Environ. 118 (2017) 40–66. https://doi.org/10.1016/j.buildenv.2017.03.021.

[26] O.O. Osunmuyiwa, S.R. Payne, P. Vigneswara Ilavarasan, A.D. Peacock, D.P. Jenkins, I cannot live without air conditioning! The role of identity, values and situational factors on cooling consumption patterns in India, Energy Res. Soc. Sci. 69 (2020) 101634. https://doi.org/10.1016/j.erss.2020.101634.