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Windows: Socio-Environmental Dimensions in Palestinian Residential Buildings

Dua Mallah[1] , Muhannad Haj Hussein[1,*]& Nisreen Arda[1,2].

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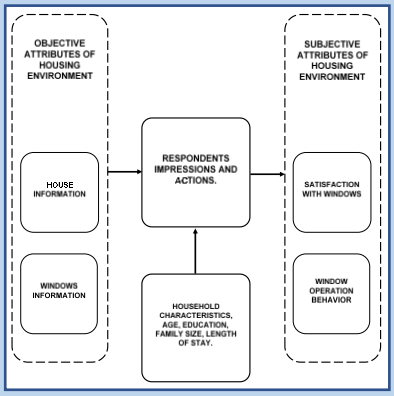
Abstract: People spend a significant portion of their lives indoors. Nowadays, windows are the essential architectural element that allows users to have contact with the outside world. This contact has an important impact on our physiology, psychology, well-being, and indoor environment. Understanding the physical and behavioral (social) characteristics of this element in the Palestinian residential building is still insufficiently explored. A cross-sectional survey of 272 respondents was conducted to investigate the openings' characteristics and user's behavior to assess their influence on residents' satisfaction and indoor performance. This assessment was based on the concept that residents' satisfaction with their homes is a measure of buildings' performance in meeting users' needs, expectations, and aspirations. The findings show that the physical properties (i.e. Window wall ratio, Window floor ratio, position, orientation, etc.) of windows do not meet the minimum threshold of sustainable and energy-efficient values (i.e. Daylight, thermal comfort). In addition, the survey analysis determines the driving parameters and their corresponding variations influencing window operations in different periods of the day and season. The culture plays a central role in the Palestinians' window operation behavior.



Keywords: Residential buildings; window design; cross-sectional survey; indoor environment; users' behavior; privacy; Palestine.

INTRODUCTION

Most people spend 90% of their time indoors [1,2], where usually they spend more than half of that time inside their homes[3]. Hence, the home design should be socially and culturally compatible with its inhabitants and should maintain their beliefs and expectations, health, comfort, and general well-being with a minimum impact on the natural environment.

In 2020, most of the global population has been put in lockdown due to COVID-19 pandemic[4,5]. Similarly, the majority of Palestinians were in lockdown and spent most of their time inside their homes. In response, the home has become a location for a wider range of daily activities that previously occurred outside its boundaries.

The unfamiliarity of this situation increases the need to understand how much the residents are satisfied with the current building design. Besides, how they behave and interact with their building envelope to adjust the built environment to reach the desired indoor air quality and comfort, to keep themselves healthy during the lockdown, and how their behavior may influence their comfort and energy consumption.

Fenestrations (i.e. windows) are one of main building envelope elements that play an important role in home social-ecological factors. They play a vital role in providing natural lighting, visual, thermal and acoustical comfort[6–9], also provide weather-tightness, privacy, natural ventilation, a feeling of accessibility, and the opportunity to leave the building in extreme situations.[10] and [11,12] mentioned that fenestrations in building envelopes are critical components that acquire solar energy and daylight, facilitate a thorough view of a building, and influence the overall building energy consumption[13], therefore, operable fenestrations, have been favored for many buildings as a low-carbon solution.

According to V. Fabi et al and M. Schweiker et al, [14,15], windows influence the performance of home building significantly. G. U. Harputlugil et al, results indicate that being at home and operating windows had the most significant impact on internal loads and comfort levels throughout the year [16]. Additionally, during the winter, the amount of transparency in the curtains affects the temperature inside. S. Pan et al, and J. Zhao and Y. Du stressed that a good selection, and use of windows can provide a comfortable indoor environment with minimum energy use, while improper windows selection, and use may result in a bad indoor environment and may also cause a great waste of energy[17,18]. These are also important from an architectural standpoint in adding aesthetics to the building design. Fenestration systems are responsible for 60 percent of potential energy losses in buildings, according to reports, their transfer coefficient is often five times larger than that of other components of a building's envelope.[18]

1 Department of Civil and Architectural Engineering, Faculty of Engineering and Information Technology, An-Najah National University, Nablus, Palestine. d.mallah@najah.edu
* Corresponding author email: haj_mj@najah.edu
2 E-mail: nisreen.ardda@gmail.com

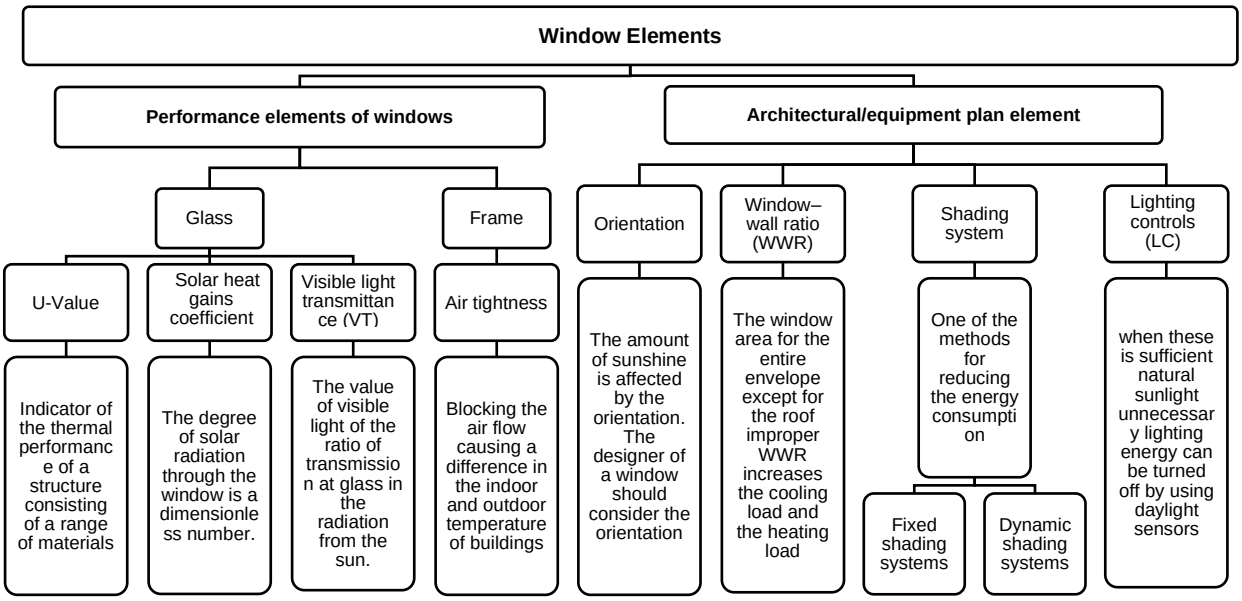


Figure (1): The elements affecting windows efficiency and performance. [107][108]represented by authors.

The operation of windows ,according to Y. Chen et al, is a very important factor for high-performance natural ventilation [19]. Also, in most residential buildings, windows are controlled manually by the occupants, which significantly impacts occupants' comfort and energy use [7–9]. humanities and social, cultural and ethical values plays an important role in sustainability [20], therefore, cultural dimension is important because attitudes towards privacy can significantly differ across cultures, potentially influencing behaviors like window opening. For example, individuals from cultures that place a high value on privacy may open windows less frequently or be more concerned about when and how they do it.[21,22]

When studying the residential vernacular buildings in the Mediterranean region, observation indicates the use of small exterior openings as a strategy to maintaining privacy and mitigate climate impact[23]. Some solutions were implemented for achieving this, one of these solutions is the “Mashrabiya”[24], also, inward orientation of the majority of the openings into the courtyard. In addition, “Kizan” small openings in the external wall a kind of perforated facade, was generally used on building roofs or terraces. Privacy cannot be ignored here since it is the most important factor of the design in order to minimize the possibility of be seen or heard by the people outside. [25,26]

This research will identify the main influencing factors, which affect the occupant’s windows opening behavior and also explores residents’ satisfaction with the current window design.

Windows in literature review

The literature shows a variety of approaches that is being used to asses and examine the role that windows can play architectural design.

Subjective approach, investigating the windows opening behavior, or evaluate occupant’s satisfaction evaluation.

Objective approach that focusses on the elements of windows. Figure1, illustrates the different elements affecting windows efficiency and performance in the literature, where most of them were used later on to develop the questioner and investigating the windows in Palestinian residential buildings, also it helped to provide the knowledge needed, in regard of the elements, and how the windows are being investigated in literature.

There are limited studies investigating the users window satisfaction in residential buildings, one of the few studies which focuses on residential buildings, was recently conducted by J. Kim et al, designing a new tool (Seemo) to help architects at the early stages of design to have better understanding and prediction of occupant’s view satisfaction in residential buildings. [27]

Other type of buildings, particularly offices, have been heavily investigated, worker’s satisfaction of the workplace environment applied questionnaires, field measurement, simulation and virtual reality to investigate the participant’s spatial perception, visual comfort[28,29], satisfaction with the amount of view[30], the amount of sunlight penetration[31,32], window size[33], number of preferred windows in a space and its relation to energy consumption[34] and also, the effects of window size, on worker’s mood, emotional response and psychological satisfaction[35], it has been found that desk location and layout have the largest contribution to the worker’s satisfaction.

For several years’ great effort has been devoted to study the resident satisfaction with dwelling, being a complex issue, several disciplines have different perspective for approaching the subject, most of the studies starts with post occupancy survey then implementing different analytical methodologies to evaluate the user’s satisfaction. Majority of the research in this area came to the conclusion that windows related issues have great impact with dwelling perception and satisfaction. [36–38]

Mirdah’s research discuss living in apartment, found that 'Management and Maintenance' of the apartment was the most important factor affecting resident’s satisfaction, but also, described the ‘Ambient Environment’ component (which investigate, lighting and Ventilation adequacy in unit, Veranda(s) location, Entrance of apartment building, Location of windows), as an important factor, with high coloration between the lighting adequacy and ventilation adequacy, in addition, the location of windows could be the most important criterion for ensuring good lighting and ventilation[39]. Air quality was found to have the

highest impact when investigating the Impact of the different aspects of indoor environment on the occupants' overall satisfaction in Swedish dwellings.[38]

Table 1 demonstrate (Subjective) studies on stochastic aspects with a focus on observing window use [17] window opening behavior[11,40–45], Predicting Window opening behavior[46,47], interaction with windows and lights[48].

Results indicated that window opening is strongly related to the outdoor air and indoor temperature, concentration of room CO_2, relative humidity, wind speed, outdoor PM2.5 concentrations, solar radiation and sunshine hours, also open-window duration differed throughout the seasons, time of a day, occupancy pattern and window orientation, other design and non- thermal factors impacted the occupant's adaptive behavior, such as privacy and safety, non-availability of controls, operation and maintenance of controls, mosquitoes, noise, occupant's attitude, age and tenure. Most of the research in this area was conducted based on filed measurements and analysis (Gauss distribution, Logistic regression, Multivariate logistic regression…) with an end goal of improving the prediction of window opining behavior, which leads to more accurate computer simulation results and bridging the gap between real and simulated energy consumption.

Table (1): (Subjective) Perception, Behavior Studies of windows in literature review.

Source	Location	Building use	Method	Analysis target
[49]	UK	Residential buildings	Field measurements and computer simulation	Relationship between window operation behavior and thermal and air quality
[50]	China	Residential building	Field measurements and Logistic regression	Window opening models
[51]	UK	Residential building	Field measurements and computer simulation	Window operation behavior and indoor air quality
[52]	Belgium	Residential building	Survey	The extent of the habitual behavior and to identify the types of windows use habits.
[53]	Tianjin, China	Residential building	Cox model survival analysis	Opening and closing windows
[54]	Nanjing, China	Residential building	Field measurement	Window opening behavior
[55]	China	Residential	Field study measurement	Window-opening behavior
[56]	UK	Residential building	Measurements stochastic model multivariate logistic regression	Opening and closing windows (change from one state to another)
[57]	Southern Germany	Residential building	Field study logistic regression	Window opening behavior
[58]	Denmark	Residential	Measurements Statistical analysis Multivariate logistic regression	Defining window opening behavior patterns for simulation purposes
[59]	Beijing	Residential building	Field survey	Window and interior door opening /closing
[60]	Hyderabad, India	Residential building	Field survey	Natural ventilation for thermal comfort in

In term of objective studies which focuses on deterministic aspects, the office buildings being the dominant type, energy loads and consumption[18,61–65], energy demand and visual comfort [66,67], energy efficiency[68], daylight performance[69–71], thermal comfort[1,19,72–74], thermal performance [75,76], and acoustical performance [77–83], usually just one, or several, individual office room or single room are investigated using simulation or experiments. Table 2 summarize the Objective studies; the residential buildings are not adequately represented with the least number of researches. It is also noted that the computer simulation is the most common method to inquire information regarding windows thermal and visual performance. While laboratories experiments are more common when investigating the acoustical performance of windows. These studies investigated windows performance in regard of different windows design factors such as window size, position, window to wall ratio (WWR), window-to-floor ratios (WFR), orientation, Type of glazing and frames, U-value, solar heat gain coefficient (SHGC), visible transmittance (Tvis). Previous research has documented that different window design aspects (WWR, WFR, Type of glazing and frames, shading …) in different facade orientations greatly affect the cooling, heating and the lighting energy consumption, also shading with roller blinds can affect the airflow through open windows[84].

Table (2): Objective & Physical building energy and performance Studies in literature review.

Source	Building use	Location	Method	Analysis target
[85]	Residential Buildings	China	Energy balance equation.	Rule of window-to-wall ratio on energy demand
[86]	----------	----------	Multi-objective optimization	Energy consumption, thermal environment, visual performance and sound insulation effect
[87]	Residential Buildings	Chongqing, China	Computer simulation	Effect of Window Openable Area and Shading on Indoor Thermal Comfort and Energy Efficiency
[88]	Residential Buildings	JORDAN	Computer simulation	Impact of window shading on the thermal performance
[89]	Residential buildings	Hong Kong	Computer simulation	Cooling energy consumption Indoor PM2.5 exposure concentration
[90]	Residential (case study)	Hong Kong (case study)	Computer simulation Building information modeling	Thermal comfort and energy performance
[91]	Residential	Sizhai village, China	Calculation method	Shading performance
[92]	Residential buildings	-	Computational experiment Mathematical model	Heat parameters of windows
[93]	Residential	Vancouver, BC, US.	Computer simulation Building information modeling	Energy load

Most of the literature investigate windows elements [efficiency and performance), user behavior or building satisfaction, with no regard to the social and cultural aspects which can affect these studies, especially in residential buildings. Although advances have been made to optimize window design, predict preferences and control behaviors driven by physical factors such as, daylight, sunlight, heating and ventilation, the role non-physical motives have on user behaviors is still not well understood. Recently, very few studies consider the influence of non-physical factors in regard of windows design, operation and satisfaction. a study that highlights how culture has important implications on window preferences of shading control, by using an internet-based questionnaire on a world wide scale during the

pandemic, showed that Arab respondents prioritized privacy more than non-Arab respondents. [21]

Other studies investigate the Contribution of the vernacular architecture to the sustainability in the Mediterranean. Reveals that openings are very important in the design process, specifically their area, location, and orientation. In the old city houses, it was clear that openings are very important either for privacy or passive cooling techniques. The number of openings was restricted to control heat gains and losses, and oriented to collect the needed cool breeze in hot summer days, and sunlight in cold winter days, besides achieving the suitable level of acoustical and visual privacy. However, this strategy is missing in contemporary buildings, as openings were located regardless of the sunlight or wind direction in summer and winter, and privacy was not attained. [25]

This study investigates the socio-environmental dimension of windows in residential buildings in the West Bank, Palestine. This investigation is vital to understand the current situation of these elements in the Palestinian context and the drivers of window operation behavior, which, to the best of authors' knowledge, are never approached before in any previous studies. In additional to the fact that there is no building code in Palestine has control on this element of building except municipality regulation that require one opening in each room in order to issue the construction permit from the municipality.

This research will contribute to filling the gap identified in the state of the art, not only in terms of determining the physical status of the openings but also in terms of determining the relationship between windows and their corresponding spaces, as the starting point for improving the design of residential building windows from socio-environmental aspects.

MATERIALS AND METHODS

The research method used in this study is an online survey, which allows for convenient data collection from a large sample size. Survey methods have been widely used in research to determine windows opening behavior and also exploring residents' satisfaction [2,3,7,15,21,52,94,95]. An internet-based questionnaire targeted Engineering faculty student at An Najah National University (ANNU) and their families. A total of 786 students were surveyed. Of this number, 272 representing 33.3% completed the questionnaire. Choosing students to conduct the study was necessary due to fact that ANNU is a semi-public institution, the students' sample represents the different cultural and economic status in West Bank, and therefore, it can represent most common residential buildings in West Bank. 56.3% of respondents' age ranges between 18-25 years, followed by 25-35 years (30.1%). 65.40% of respondents were female, which is consistent with the current gender distribution at the Faculty of Engineering.

The questionnaire aims to evaluate the socio-cultural and environmental role that the architectural openings could play on the indoor quality of contemporary housing in Palestinian cities from students' and their families' perspective. The developed questionnaire was in Arabic, where all the students found to be comfortable with. Pilot questionnaire-based comfort surveys were done prior to the actual surveys, and feedback from students and professors was integrated into the final version of the questionnaire.

The questionnaire was designed based on the review on the "drivers" of window opening behavior in residential buildings conducted by Fabi et al. and Carpino et al. review on the use of questionnaires in residential buildings (collected data, methodologies and objectives). The questionnaires consisted of four sections: (1) socio-demographic information (age and gender), social information (smoking behavior, respiratory diseases). (2) contextual information (dwelling type, dwelling area, room type, room orientation, room area, floor height, number of floors, duration of the residence). (3) Architectural opening information (number of openings in each room, orientation, position, dimensions, materials, shading). (4) The level of satisfaction and patterns of use of architectural openings (sunlight satisfaction in each space, opening and closing patterns of windows and shading elements, the use of artificial lighting, cooling and heating devices).[14,96]

The survey questions investigate the main spaces (living room, kitchen and the respondent bedroom) in each dwelling. In accordance with the objectives of the study, both user satisfaction measurements (subjective variable) and design parameters, (objective variables), were selected based on the literature review. The questionnaire is structured around 43 closed and open-ended questions. The frequency distribution approach was used to analyze the data from the questionnaire. This research will only look at the questions that are relevant to the objective of this article (i.e. the concept of architectural openings). Chi-Square Tests were used to determine the statistical significance of variations in responses among individuals. Sphinx iQ2© was utilized to conduct the analysis.

RESULTS AND DISCUSSION

Socio-demographic characteristics

About half of the respondents live in Nablus, the city in which ANNU is located, and about 30% live in the cities of Jenin, Ramallah and Tulkarm, which are located near Nablus and are of a similar local climate. It is worth mentioning that 87.80% of respondents own their houses, which is consistent with the findings of the Palestinian Central Bureau of Statistics (PCBS). Moreover, 58.1% of participants have been living in their homes for more than 10 years, and only 7% have been in their homes for less than 1 year.

Table (3): Occupants' information.

Characteristics	Categories	% Of respondents
Age	18-25	56.30%
	26-35	30.10%
	36-45	8.10%
	46-55	2.90%
	More than 55	2.60%
Gender	Male	34.60%
	Female	65.40%
education	high school	2.60%
	bachelor's degree	83.10%
	Graduate studies	14.30%
How long have you been living in your current home	Less than a year.	7.00%
	1-3 years	11.80%
	4-10 years	23.20%
	More than 10 years	58.10%

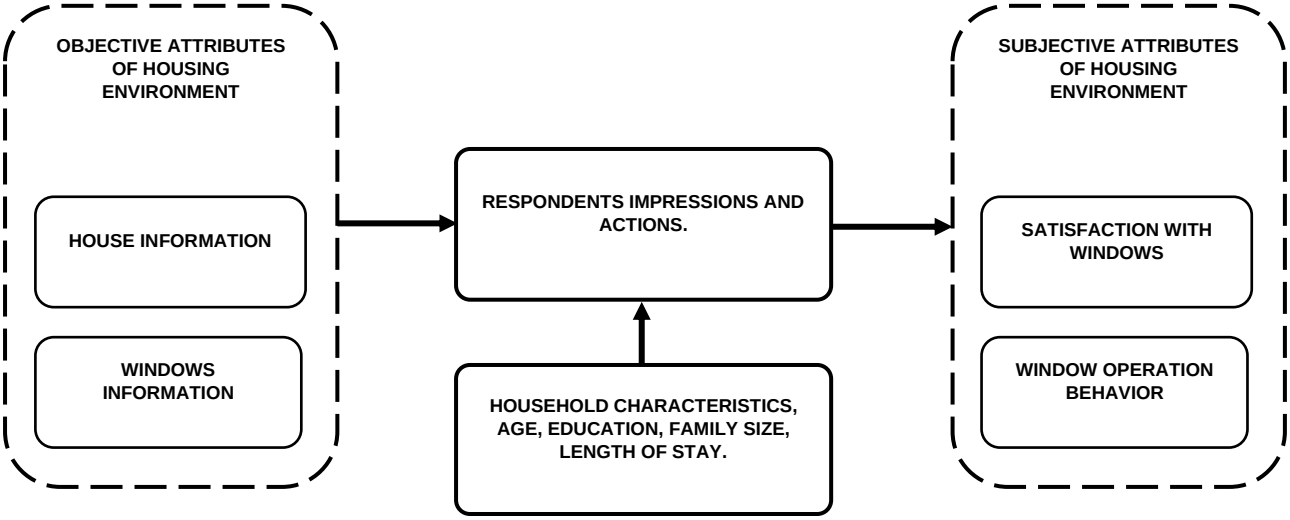


Figure (2): Flow chart of the adopted methodology.

Housing characteristics

The majority of participants (56.3%) had an interior building height of 3m, while 33.8% (3.1-3.5m). table 4. The most common area for kitchens, bedrooms and living rooms is (12 m²). However, the common area for guest rooms is (16 m²).

Table (4): main house characteristics.

House height				
Categories	**% Of respondents**			
less than 2.5 m	2.60%			
3 m	56.30%			
3.5 m	33.80%			
more than 3.5 m	7.40%			
Rooms area for each space				
Categories	% Of respondents			
space name	**living room**	**Kitchen**	**Bed room**	**Guest room**
No room	2.21%	0.00%	0.74 %	9.93%
less than 9 m^2	7.35%	21.69%	13.97 %	5.51%
12 m^2	29.41%	33.46%	32.72 %	25.00%
16 m^2	22.79%	23.90%	27.57 %	29.04%
24 m^2	25.00%	15.81%	18.38 %	17.65%
more than 25 m^2	12.87%	4.41%	5.51 %	11.76%
Number of opening in each space				
Categories	% Of respondents			
no opening.	18.38%	2.21%	1.10 %	9.19%
one opening	34.19%	42.65%	38.24 %	31.25%
two openings	27.57%	44.49%	47.43 %	33.09%
more than two	17.28%	10.66%	13.24 %	26.47%

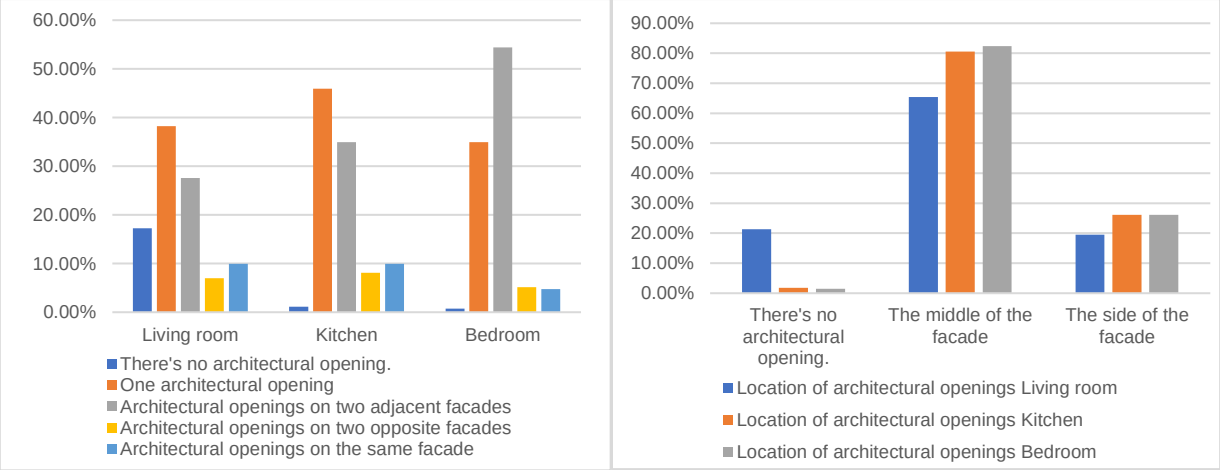
Architectural openings (windows) characteristics

Regarding the number of windows in each space, having one window in the living room is the most common (34.19%), followed by two windows (27.57%). In kitchens and bedrooms, having two windows is the most common situation with 44.49% and 47.43% respectively, followed by one opening situation 42.65% and 38.24%. Finally, similar to the kitchen and bedrooms, having two windows (33%) then only one (31.25%) is the common situation in the guest room.

It is noticed that 95.2% of openings have aluminum frames, while 90.4% of openings are sliding windows type. As for the type of glass, double-layered glass is the most common case at 42.28%, followed by single-layered glass at 37.50%.

Moreover, it was found that 88.97% of participants used interior curtains, followed by window screens mesh net at 59.93%. Around 42.28% of the windows have exterior roll blinds. Other features including flowers, cantilevers, and overhangs were present in 20.22%, 10.29% and 4.41%, of residential structures, respectively. According to the earlier findings, the average of Palestinian is more likely to protect themselves from the sun by employing internal barriers than by using anything external.

The majority of openings are located on one facade in kitchens and living rooms, whereas the majority of openings in bedrooms (54.4%) are located on two adjacent facades. The investigation about the position of openings in the facade shows that most of them are located in the middle of the facade of the space. This is present in 65.44% of living rooms, 80.51% of kitchens, and 82.35% of bedrooms, see Figure 3.



(A) **(B)**

Figure (3): Window's position: (A) windows distribution in the space and (B) windows location in the facade according to the space.

Windows area

All of the spaces have a common window height of 120 cm, with a common window area of 1.44 m^2 and 1.86 m^2 for this common window height, respectively, see figures 4 and 5.

The relationship between window dimensions and its space

Common Window to Wall ratio (WWR)

The window-to-wall ratio (WWR) is the ratio between the transparent area and total façade surface. WWR is one of most crucial aspects that deeply impact the balance between daylight and energy[97]. WWR is considered as an influence factor for energy balance[98], including cooling and heating energy use [89]. The selecting of large area of windows of clear glass facing south, east and west can result in saving more energy and a reduction in heating cost in winter [99].

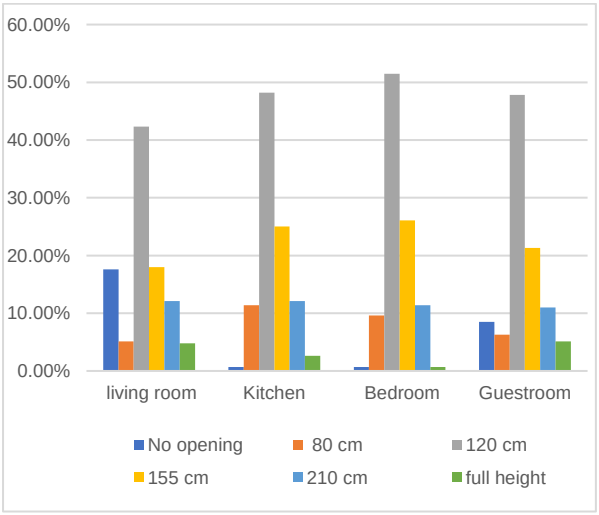


Figure (4): Windows Height.

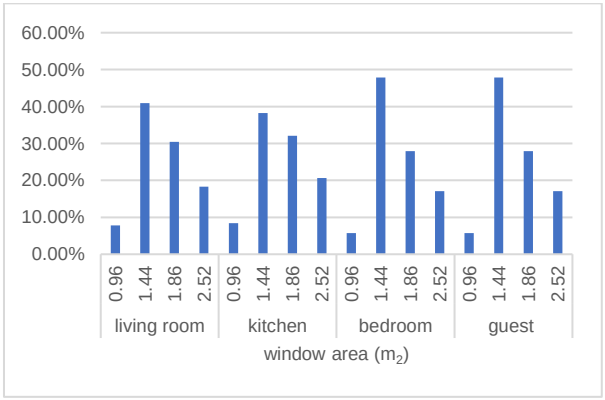


Figure (5): Openings area for the common height of architectural openings.

Many studies investigated the optimum WWR for different functions, climates and orientations [100]. Under European climate, WWR was generalized in a relatively narrow range of 0.23 < WWR < 0.31, and only south-facing units in a very warm or very cold climate will have WWR out of this range [99]. On the other hand, 20% of WWR is recommended in moderate climate. However, ANSI/ASHRAE/IES standard 90.1-2010 suggested 40% as the maximum WWR [101]. All the derived WWR in this study is lower than 20%, see Table 5.

Table (1): Illustrates the common Window to Wall ratio (WWR) of investigated residential building in West Bank.

Space	common Space width (m)	common Space height (m)	common window area m^2	wall area m^2	Window wall ratio
Living room	3.5	3.0	1.44	10.5	0.137
Kitchen	3.5	3.0	1.44	10.5	0.137
Bedroom	3.5	3.0	1.44	10.5	0.137
Guest room	3.5	3.0	1.86	10.5	0.17

The window area in the living room, kitchen, and bedroom was not influenced by the wall area, as there is no scientific indication to suggest a correlation, regardless of the wall area, a standard window area of 1.44m^2 was consistently used. However, a scientific indication does exist for the effect of wall area on window size in the guest room. Specially, when the wall area is 16.5m^2, the window size increases to 2.52m^2. Also, when the wall area is 19.5m^2, the window area increases to 4.2m^2, providing a larger window area to correlate with the larger wall area.

Table (2): Summary of chi-square: influence of wall area on window area.

space	chi2	ddl	1-p
living room	6.94	8	45.72%
kitchen	12.18	9	79.67%.
bedroom	9.54	9.54	85.44%.
Guests room	55.78	16	>99.99%

Window to Floor ratio (WFR)

WFR is another important key parameter that helps to assess the quantity of daylighting and affects the quality of interior design of buildings[102]. Nowadays, the intent of all sustainability rating is to provide residents with a connection between indoor and outdoor spaces by introducing daylight into the building's regularly used internal regions in order to create a desirable internal space in terms of natural lighting and temperature[103]. Currently, WFR is integrated in building codes of countries, which is not the case of Palestine where no building code exists yet. The National Building Regulations of Iran, for example, requires a minimum of 12% WFR to provide sufficient daylight for primary spaces in a residential building (i.e. living room, dining room, kitchen and bedroom)[102]. In addition, when side-lit windows with a light transmittance of 0.75 are implemented in nearly-zero energy residential structures, the Danish building code only demands a minimum WFR of 15% in central rooms[104].

Table 7 demonstrates the results of crossing the room area with the window's area. For the living room, kitchen and bedroom the common room area is 9-12m^2. However, for the guest room the common area is 12.5-16m^2.

Based on the previous results, we derive the common windows' area in relation to common space's floor area, see Table 7. All the derived WFR in this study falls under the minimum recommended WFR (12%) except the kitchen.

Table (3): derived common WFR in relation to commonly used windows and space area.

Space	common area (m^2)	common Window area m^2	window floor ratio
Living room	12	1.44	0.12
Kitchen	12	1.86	0.155
bedroom	12	1.44	0.12
Guest room	16	1.44	0.09

The window area in the living room, bedroom, and guestroom showed no correlation with the room area, as there is no scientific indication supporting such a relationship, regardless of the room area, a consistent standard window size of 1.44m^2 was used. However, there is a scientific indication in the case of kitchen windows, were, the room area impact window size in the kitchen. Specifically, when the room area is 16m^2, the window size increases to 2.52m^2. In opposition, when the room area is 24m^2, the window area decreases to 1.86m^2. It is important to note that the change in window size in the kitchen does not necessarily maintain larger window dimensions when the room area becomes larger.

Table (4): Summary of Chi-Square: Influence Of Room Area On Window Area.

Space	chi2	ddl	1-p
living room	9.29	8	68.17%
kitchen	33.12	12	99.91%
bedroom	7.11	4	86.98%
guestroom	3.77	4	56.16%

Orientation and window dimensions.

The most frequent windows' height is 120 cm on all orientations for all the rooms but with different frequencies for each room with the exception of the southern guest room window with the height being 155cm. However, the window's area slightly differs according to the orientation within the common window area ranging from 1.44m^2 to 1.86m^2 except for the western guest room window with area of 2.52m^2, therefore, window to floor ratio also differs slightly in different orientation for different rooms ranging between 0.12 to 0.155 m^2 for all rooms except the guest room which had larger room area.

Table (5): minimum & maximum WFR in function to common space area, crossed with orientation and common window's height and width.

Space	Space area m^2	Window Orientation	Window height cm (common)	Window area m^2	Window floor ratio m^2
Living room	12	North	120	1.86	0.155
		South	120	1.44	0.12
		East	120	1.44	0.12
		West	120	1.86	0.155
Kitchen	12	North	120	1.44	0.12
		South	120	1.44	0.12
		East	120	1.86	0.155
		West	120	1.86	0.155
Bedroom	12	North	120	1.44	0.12
		South	120	1.44	0.12
		East	120	1.44	0.12
		West	120	1.86	0.155
Guest room	16	North	120	1.44	0.09
		South	155	1.86	0.116
		East	120	1.44	0.09
		West	120	2.52	0.1575

There is no scientific evidence that the orientation has an impact on the area of architectural openings in the living room, kitchen, and bedroom.

Table (6): Summary of Chi-Square: Influence of Orientation on Window Area.

Space	Window Orientation	chi2	ddl	1-p
Living room	North	4.83	5	56.35%
	South	7.25	5	79.72%
	East	1.03	5	4.01%
	West	4.85	5	56.57%
Kitchen	North	2.38	4	33.45%
	South	10.66	4	96.93%
	East	1.24	4	12.77%
	West	3.83	4	57.01%
Bedroom	North	1.74	4	21.57%
	South	2.82	4	41.24%
	East	1.61	4	19.35%
	West	2.16	4	29.40%
Guest room	North	0.15	4	0.27%
	South	4.4	4	64.54%
	East	3.53	4	52.72%
	West	14.4	4	99.39%

Window opening behavior and space occupancy

The term 'behavior' can be defined as observable reactions of a person in response to internal or external stimuli, in which could be viewed as a method of adaptation to surrounding environmental conditions such as temperature or sunlight[8]. Pan et al. believed that the occupant's behavior is a complex process because it is influenced by a number of factors and it appears in various modes[17], where Chen et al. [8] classified the occupant's behavior into three categories time-related behavior, environment-related behavior, and random behavior. Fenestration behavior has been proven to be the crucial category of an occupant's behavior because it has a significant impact on human comfort and building performance. Pan et al.[40] stressed that inaccurate descriptions concerning the occupant's behavior related to windows would automatically

result in great deviation between building design and operation, and this deviation is often referred to as “performance gap”. As a result, bridging the gap between simulation findings and building performance requires a greater knowledge of occupant behavior in structures.

When asking the inhabitant about the time of the day they spent in their spaces we found that the guest room being the lowest used among other spaces even though it occupies larger area of the house.

In terms of how people behave around windows, there is a direct correlation between the desired time for opening windows and the occupancy of the space. Approximately 70% of occupants prefer to open windows when they enter a space, whereas more than 50% prefer to close them when they leave.

A strong relationship between window control operations and the occupant’s routine, habits or state of mind was also discovered. It should be mentioned that 84% of respondents opened windows as soon as they woke up, 54% did so before going to bed, and almost 78% did so while cleaning. In addition, 84% of people open the windows when congregating in the space.

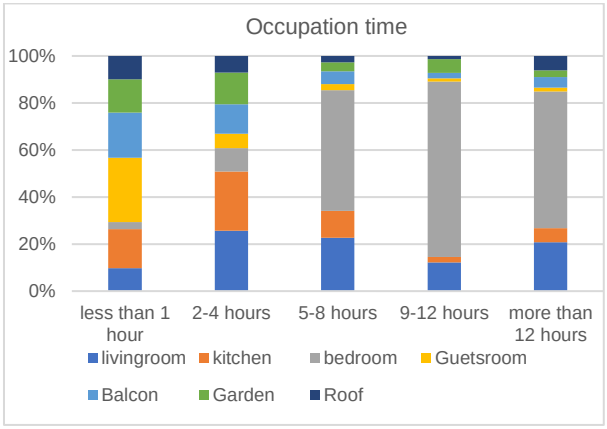


Figure (6): Time spent in each space.

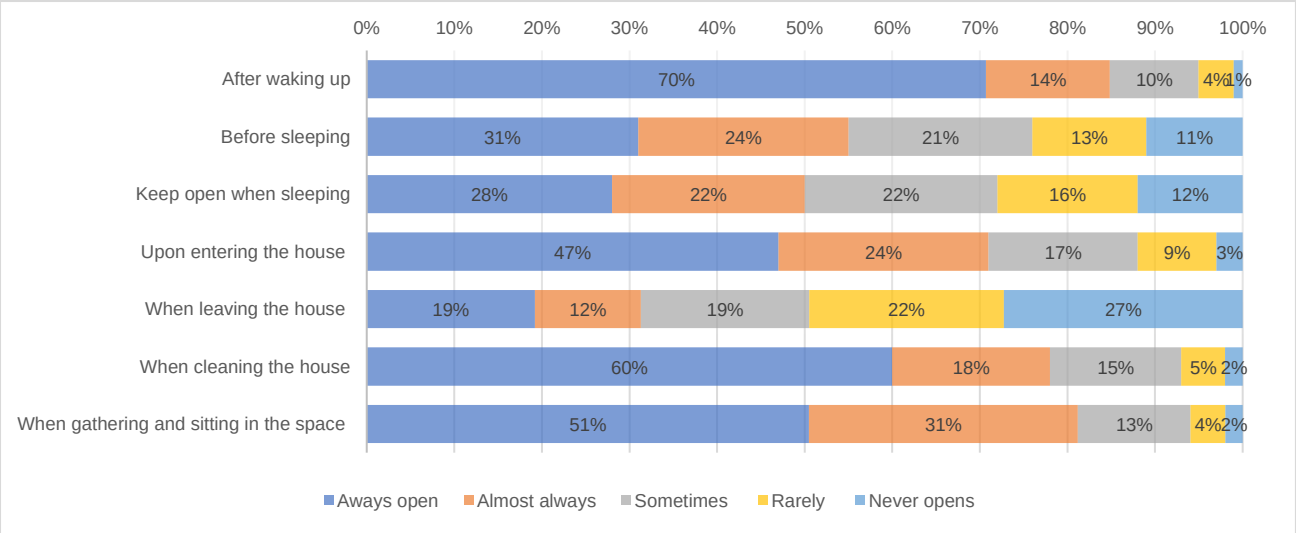


Figure (7): Window opening habits. In which of the following cases would you open windows?

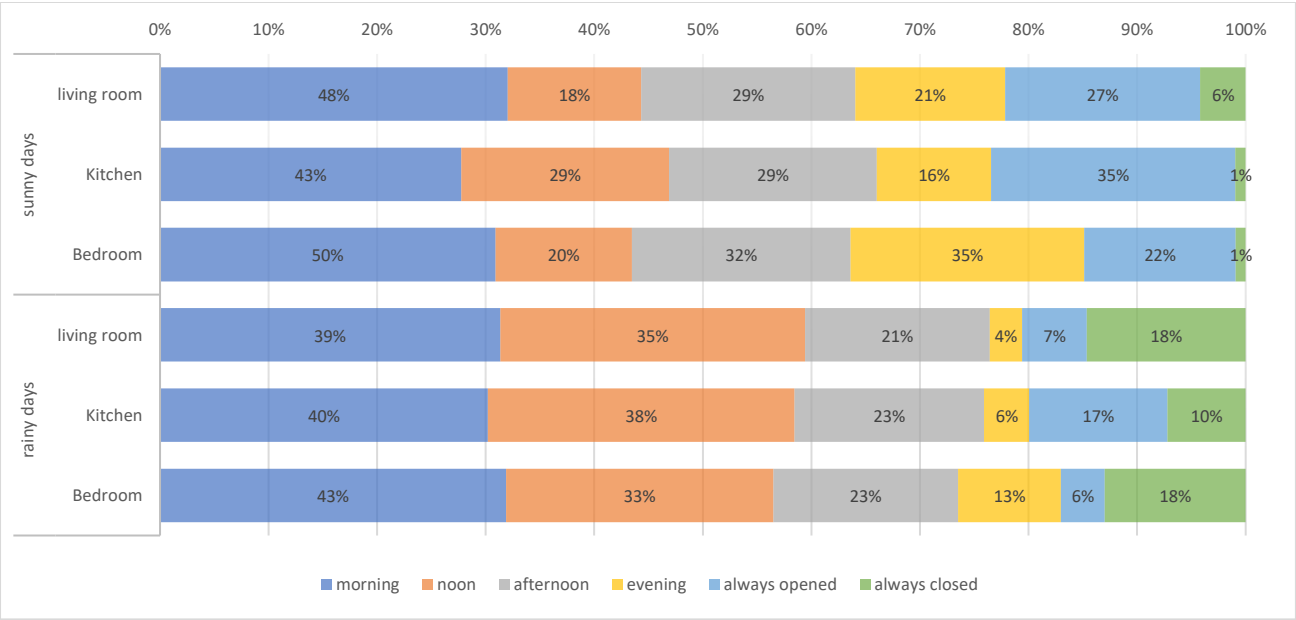


Figure (8): Favorite period to open windows

Orientation and window opening during sunny and rainy days throughout the day

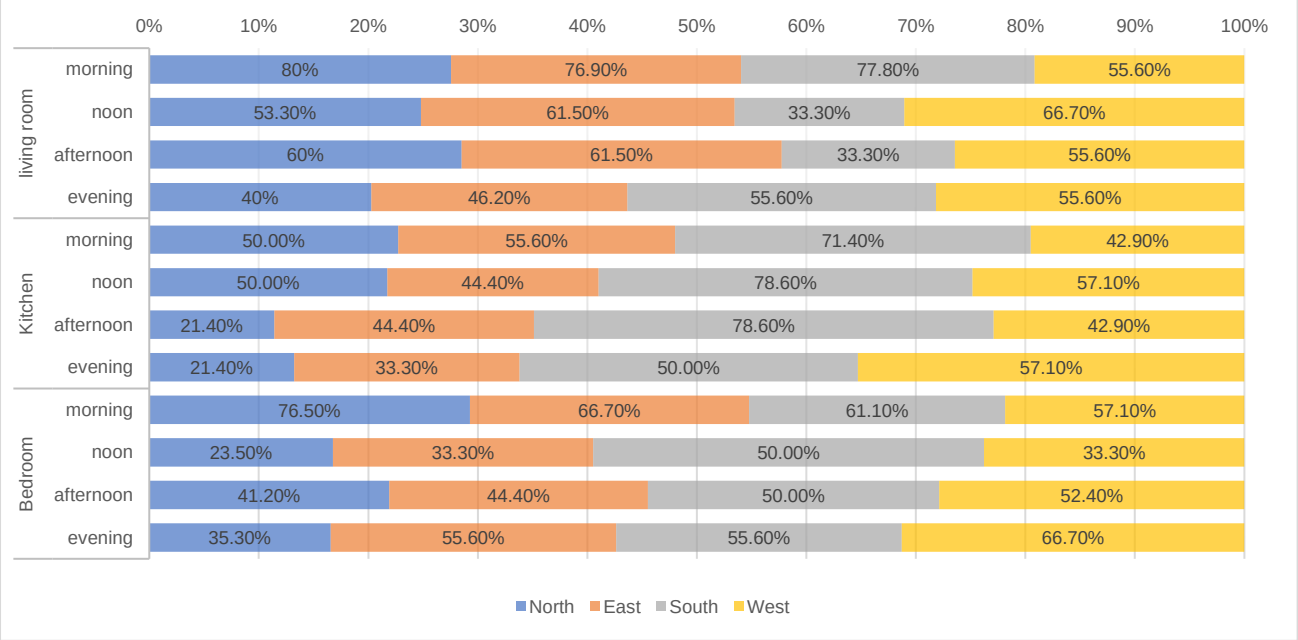


Figure (9): Window opening during sunny days.

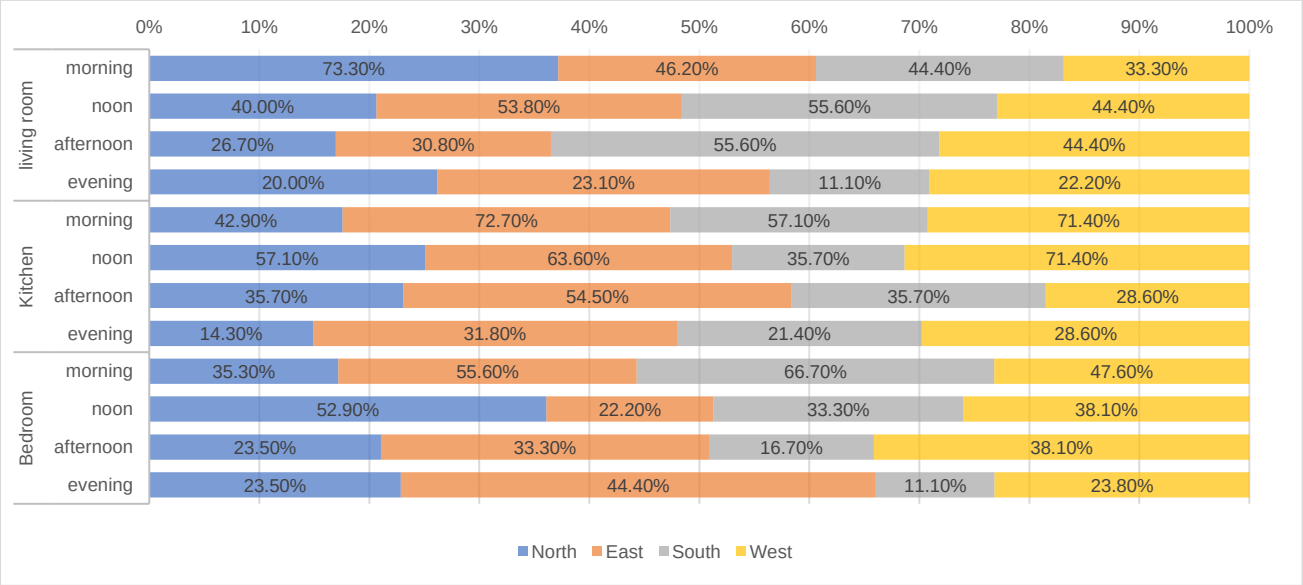


Figure (10): Window opening during rainy/ cloudy days.

When inquiring for the most preferable period of the day for opening windows in different spaces, on sunny days, the morning was the most common time. When compared to the direction, there isn't a clear effect of the direction on the opening, especially in the living room and bedroom. However, in the kitchen, the effect of the direction on the opening is evidently greater when the window is directed south, regardless of the time of day.

During the cloudy days, the majority of window opening occurs from morning to midday. The opening of the windows in the kitchen is more easterly and westerly.

The characteristics of a space have a significant impact on energy use as well as the quality of the indoor environment in terms of natural ventilation and lighting. The findings revealed that a significant part of Palestinian residents, 65% and 60%, respectively, use windows to regulate the amount of fresh air and lighting in their homes. It is also vital to note that the dust was the main driver behind window closures. figure 10 illustrates the When asked about the most influential factors in people's behaviors to open and close the window.

Additionally, when asking why people in occupied spaces draw their curtains while opening their windows, privacy was the most common response, demonstrating the importance of social and cultural factors in Palestinian window operation. This was followed by the blocking of insects and dust, preventing sun ray's penetration, harsh winter weather, and finally, preventing artificial light penetration into spaces after dark. See Figure 11.

Regardless of whether the windows are open or closed, it was customary for users to open the curtains during the day. On the other hand, curtains are kept drawn during night. However, it is seen that when the curtains are drawn, artificial lights are turned on. Figure 12

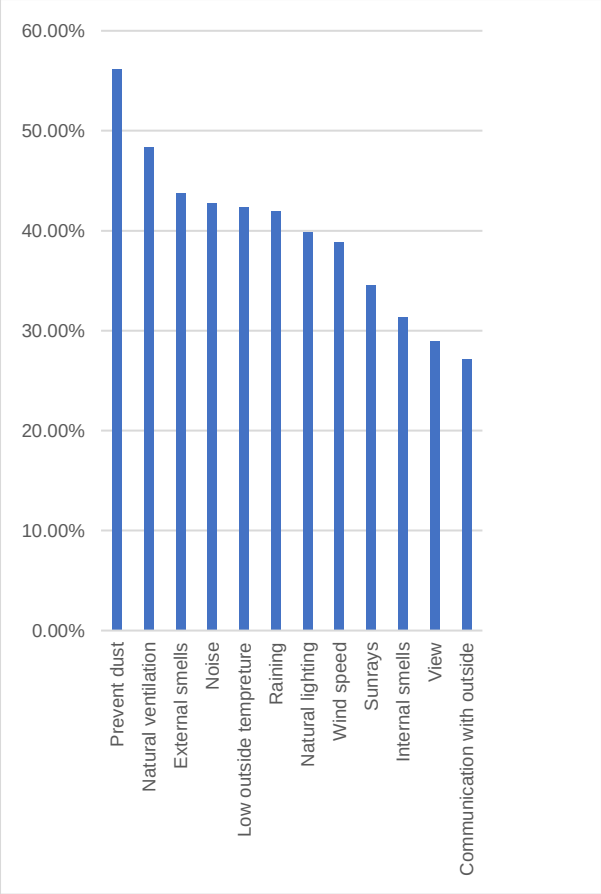


Figure (11): most affecting factors for opening and closing windows.

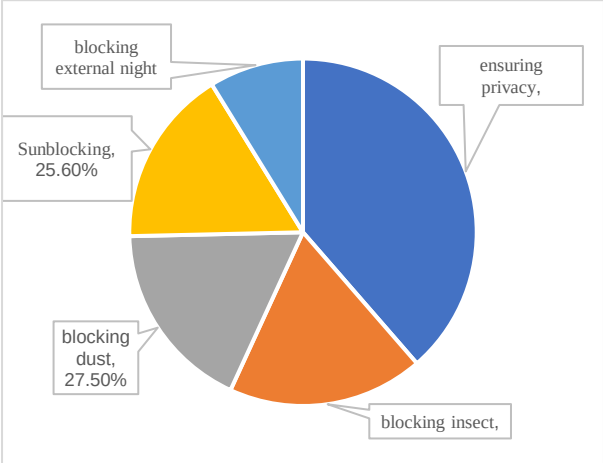


Figure (12): Most important reasons for closing windows' curtains

Occupant satisfaction

The study of users' satisfaction about sunrays that penetrating inside the living room in comparison to the windows' area showed that the common area of 1.44m^2 does not meet users' satisfaction. However, the area of 2.521.44m^2 was the preferable.

The living room, kitchen, and bedroom were the area's most frequently utilized; the guest room was not included because it was rarely used. The questionnaire's major focus was on how satisfied respondents were with the amount of solar radiation that entered their rooms on sunny and rainy days.

When asking about inhabitants' satisfaction about the solar radiations that penetrate into their main spaces (living room, kitchen & bedroom) during sunny and clear sky, the living room was the most unsatisfied in comparison to other spaces. This is due to the fact of more than 60% of investigated residential units design are based on an open plan concept, where 20% of living rooms are without direct connection with the outside (have no windows). In addition, the same results of satisfaction level achieved for cloudy and rainy days. Figure 17.

One opening was found to be more preferred in the living room than in other areas, where having two openings was preferred in terms of users' satisfaction.

When it comes to windows' glass type its notice that there is no relationship between glass type (single or double) and solar radiation satisfaction.

The analysis of orientation effect on the level of users' satisfaction in their main spaces show that south and east orientation are preferable in term of solar radiation performance in both seasons (summer and winter). However, for living rooms and bedrooms, the most frequent answer for satisfaction was for south, north, west and east orientation respectively.

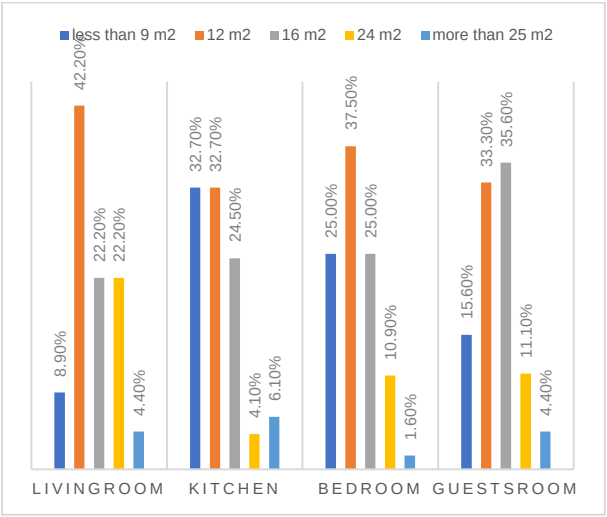


Figure (13: sunray satisfaction with the common window area for different room area.

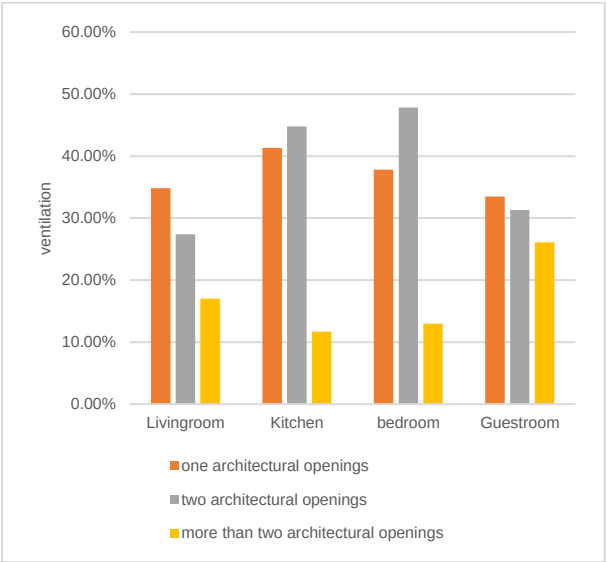


Figure (14): Frequency of using windows for ventilation based on the number of windows in each space.

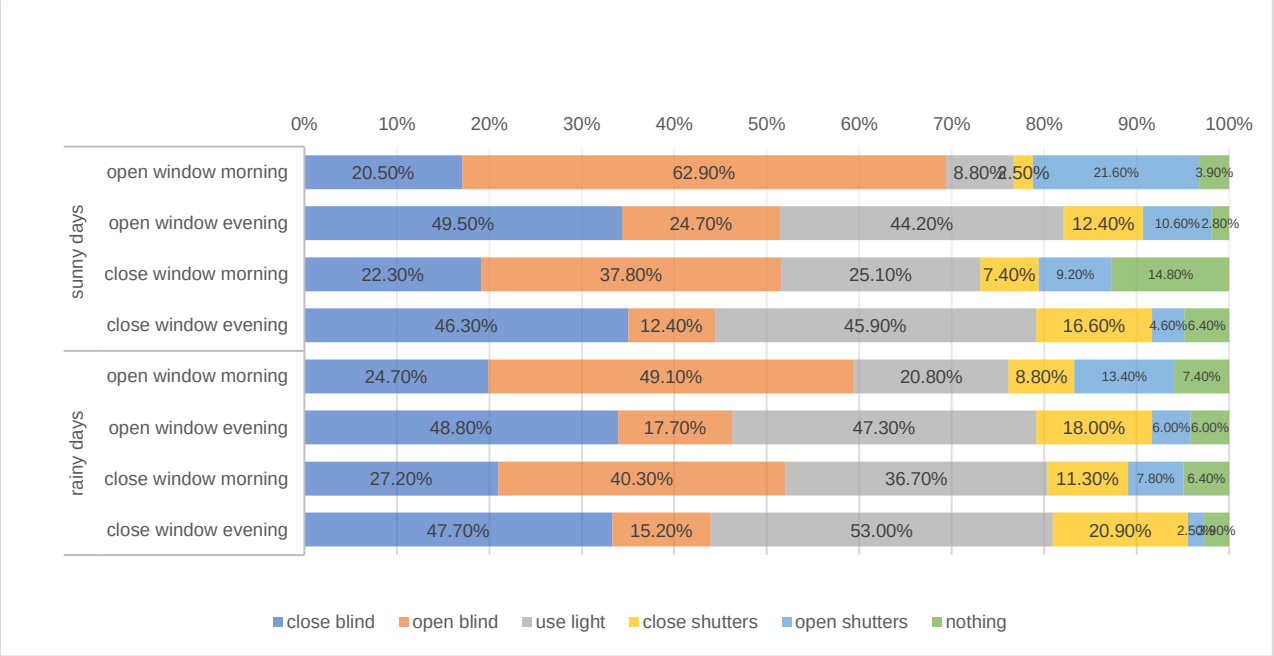


Figure (15): user behavior in sunny and cloudy days when the window is opened / closed

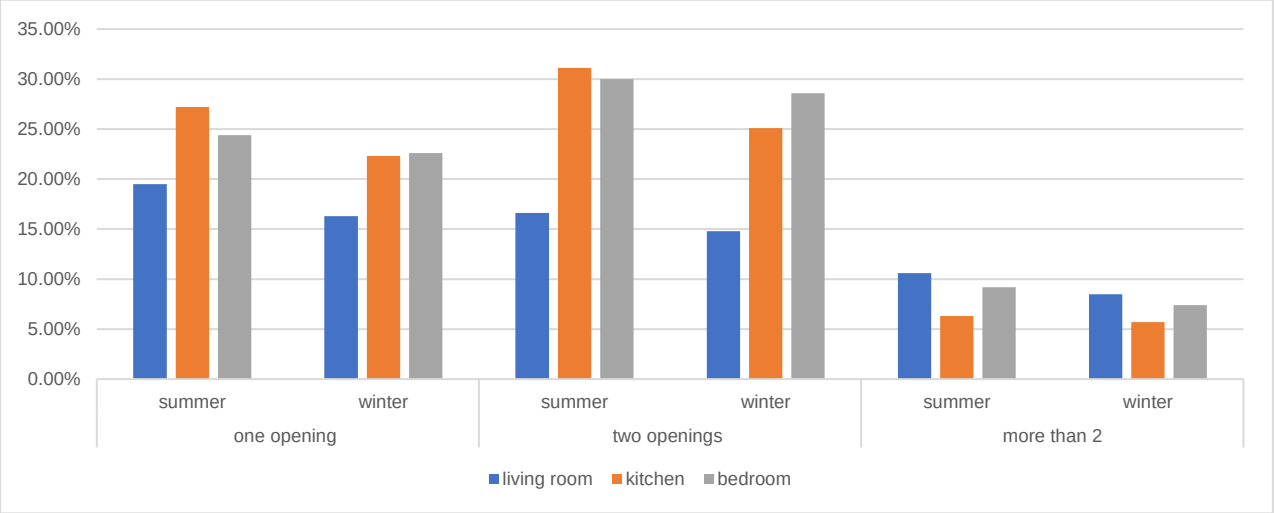


Figure (16): Solar radiation satisfaction VS number of openings per space.

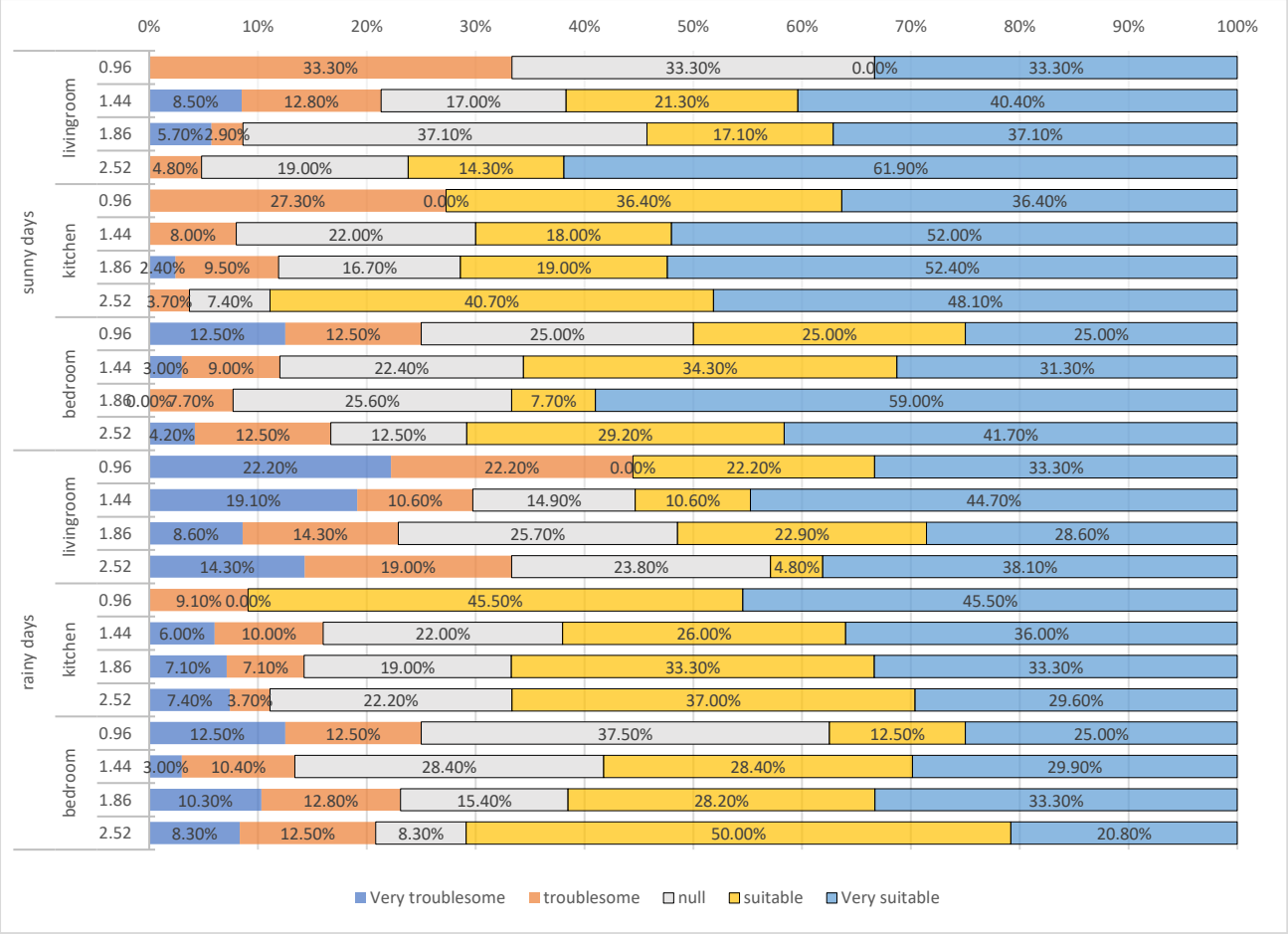


Figure (17): satisfaction with the amount of sunlight penetrating spaces for different window area.

Occupants tend to be more satisfied with the common window area as the room size gets smaller, particularly in the kitchen.

According to the results of a survey on natural ventilation satisfaction and space orientation, people are happier with natural ventilation in living rooms that are facing north. The north, west, and north-west orientations of the bedroom are preferred by its occupants. Whereas the best orientation for kitchens is to the east and south.

In addition, it has been noticed that reliance on natural ventilation increases in the kitchen (44.8%) and bedrooms (47.8%) if there are two windows. We can summarize that the respondents in the questionnaire preferred to have more windows in their spaces to improve the ventilation.

The findings show that the dependency on natural ventilation to ensure indoor thermal comfort is affected by the number of windows in each space except the guest room; where the most frequent ventilated rooms were those that have one opening.

length of residency in the house did not have a huge effect on user's satisfaction with the solar radiation, but it is noted that people living in the house for longer time are slightly more satisfied with the sunray in spaces during sunny days, 43% of occupant with more than 10 years and 35% for occupants living in the house for less than one year, also the same results have been noticed for cloudy days except for the case of the living room.

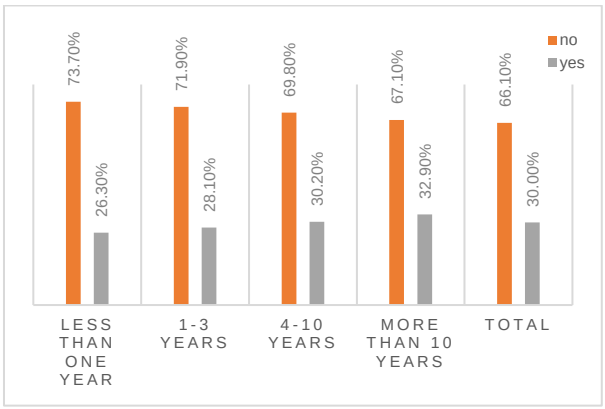


Figure (18): Do you think it is necessary to make any modifications to the architectural openings in your home? Vs no. of years living in the house.

CONCLUSIONS

This paper elaborates a qualitative survey on windows' properties and occupant window- opening behavior and their relevant influential factors for a period of two months of confinement in residential buildings in West Bank, Palestine. The results show that all these factors, i.e. window orientation, window's width, window's height, outdoor air temperatures, season, personal preference, time of day all have performed great influences on occupants' satisfaction and window-opening behavior. Main conclusions are as follows:

- There is no indicator that the designers take in their consideration the space type, orientation, locations or space area during the designing process of architectural openings. For example, there are slight differences in the dimensions, number and distribution of architectural opening in different spaces of the building. Dimensions of windows 120 cm height and 1.44 – 1.86 m^2 area are being used as standard window dimensions with no regard to the space area, orientation or function. In addition, no studies have been conducted in Palestine to determine if these dimensions are the best to be used for the best solar, visual, thermal comfort.
- Living room is a place that should be given an emphasis to improve the health and well-being of building occupants, however in the case of the West Bank residential building it got the less attention.
- Curtains play an important role in the fenestration system in the West Bank residential buildings. They are the main shading system for decreasing the sunlight that inter spaces during a sunny day and they are also mainly used to achieve privacy for the residents.
- Sunrays and natural ventilation are the most commonly used ways to achieve thermal comfort in spaces, which increase the importance of the fenestration systems in the West Bank.
- Increasing the number of windows in (the vital spaces) such as the living room is more beneficial than (the secondary spaces) such as the guest room for better use in achieving thermal comfort through ventilation.
- Culture plays a central role in the Palestinians window operation behavior, improving windows design that provides the desired privacy while maintaining appropriate function of fenestration (natural lighting, thermal comfort and visual openness) is essential.
- Keeping the window open all day long on sunny days is the common practice in the West Bank despite the fact, concluded in many studies, that opening should be kept shut at noon/afternoon to maintain a cooler indoor environment[105,106]. Therefore, raising awareness is essential to improve window-opening behavior in the Palestinian community.
- The interaction between users' behavior and the windows design need more elaborate study. Taking in consideration that the social aspect occupies the first place in thinking about sustainable housing in Palestine before any other factor.
- The survey results in this study aid in creating an overview of the preferred window operation on sunny and cloudy days, as well as the duration of occupancy for different spaces. These results will serve as input for computer-based simulations used in future objective research.

Influences from other possible factors could not be explored in this study due to the inherent limits of monitored samples., such as indoor & outdoor temperature, U-value of windows, amount of solar radiation penetrating through the window and daylight illuminance falling on the indoor surfaces. A significant effort should be addressed in the following years to improve the design of the fenestration system considering the building envelope elements, passive design strategies, and its suitability to the social-cultural factors. Future and additional research based on windows typology analysis is highly recommended as the data collection method in this paper was limited by the perception of the users and their ability to estimate the areas.

DISCLOSURE STATEMENT

- Compliance with Ethical Standards: No conflict of interest exits in the submission of this manuscript, and manuscript is approved by all authors for publication. I would like to declare on behalf of my co-authors that the work described was original research that has not been published previously, and not under consideration for publication elsewhere, in whole or in part. All the authors listed have approved the manuscript that is enclosed.
- Ethics approval and consent to participate: Not applicable
- Consent for publication: Not applicable
- Availability of data and materials; Availability of data and materials Data is available upon the request.
- Author's contribution: The authors confirm contribution to the paper as follows: The study was conceptualized and written by all authors. Survey perpetration & Theoretical background by the first author. statistical analysis was carried out by the second and first author. All authors evaluated the findings and approved the final manuscript version.
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