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Correlation between user activity at different rooftop typologies in residential buildings in a compact urban context

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Abstract

The scarcity of public open space has compelled urbanites to use residential rooftops as an interaction space. In Dhaka, rooftops are used for various social and recreational purposes which has extensively increased due to COVID-19 restrictions. During this period, few rooftops are used frequently while few are less occupied. Hence, the study identifies different variables that impact rooftop activities and finds correlations between them using the Pearson correlation coefficient. The study further shows the direction for accelerating the use of rooftops as an interaction space in residential buildings.

Keywords

Rooftop,
Dhaka's residential building,
COVID-19,
Correlational research,
Social and recreational interaction

Highlights for public administration, management and planning:

- Rooftops represent important places of public life in Dhaka.
- The variables that affect the social and recreational activities of residential rooftop space are analysed.
- Statistically significant correlations were found between rooftop occupied by various services and number of activities, floor dampness and number of activities, the rooftop occupied by various services and a comfort zone with a pleasant view, parapet height and number of activities, and parapet height and safety.
- The paper sets recommendations for designing and managing rooftop spaces.

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1 Introduction

A house is a space where people not only live but also socially interact with each other (Ozaki 2001). In traditional Bengali houses, this interaction and other common activities occur in courtyards which have influenced the residential building design of Bangladesh for a long time. However, in the last few decades, Dhaka, the capital of Bangladesh has witnessed an increased number of high-rise apartment buildings omitting courtyards which have compelled its users to use rooftops as an alternative space for social and recreational interaction. Also, to accommodate people who are continuously migrating from rural areas to Dhaka city for better livelihood, high-rise buildings are built which has reduced the overall open space of Dhaka. As a result, in-house courtyards have disappeared, reducing the interaction opportunities of the urbanites. Still, to serve the people's desire for community and recreational interactions a new interaction space like courtyard has been evolved which is rooftop. Presently, it is used as a semi-public space in Dhaka serving as a vertical courtyard.

Additionally, due to consequent loss of public open green spaces within proximity the rooftop spaces have become the sole social and recreational interaction space for the city dwellers of Dhaka. The rooftop has been used for various purposes, e. g., gossiping, drying clothes, gardening, walking, and playing (Barua & Ikbal 2012; Iffat & Fatemi 2012). Moreover, due to COVID-19 pandemic and consequent social restrictions people are being confined within their apartments explicitly using the rooftop as a breathing space (Barua & Ikbal 2012; Iffat & Fatemi 2012) which ultimately became a semi-public community space for all the residents living in a particular apartment.

However, the user experience of the rooftops is not satisfactory as it is not designed consider-

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ing the social and recreational aspects and several issues such as lack of maintenance, low parapet height, unorganized spaces with limited facilities and improper planning of service infrastructures hamper rooftop activity. As a result, although few rooftops are used extensively, few are less occupied. Therefore, the study assumes that there are relations between different rooftop types with the total number of activities. Thus, the study explores the uses of rooftop and the causes behind limited rooftop use through a correlational research approach. To find out the constraints that are hindering spontaneous rooftop activities and minimizing the opportunity for utilizing it as an improved public space, the study identifies the variables influencing different rooftop activities and explores the correlation between them through correlational research. Correlational research method is particularly chosen for this study considering the complexity, dynamism and diversity of user activity. The research questions of the study are, "which variables are affecting the social and recreational activities of residential rooftop space?" and "what are the correlations between different rooftop activities and the physical entities of a rooftop?" The objective of the research is to find correlation between different physical entities or typologies of rooftop with the activity of the people to assist architects to design a robust rooftop space. Finally, the study will recommend possible indicators that need to be improved for developing a robust rooftop space.

2 Literature Review

2.1 Emergence of rooftop as a social interaction space

Behind the changes of house forms in urban context there are some economic and political forces which basically depict not only its changing process but also the developing process of nature. Community and social interaction among people are changing because of the shifting pattern of the house forms in urban areas and some other forces e.g., technology, culture and politics. Moreover, social interaction is influenced by factors e.g., population density, size of an urban area, a housing neighbourhood's social diversity and its designed environment (Abu-Ghazzeh 1999). Urbanites' living patterns in a society, social interaction and relationships are influenced by social reality. With the changing scenario of the city, the housing and its surrounding environment has influenced the changes of social life and living pattern within the city.

In Dhaka, different groups have impacted the pattern of interaction and social life of the people and thus it varies. Urban lifestyle and housing structures have transformed in Dhaka and historically the city has faced many changes because of political, social, and economic changes. This alteration began in the 1990s, when the demand of housing, high-rise building increased and diverse communities started to reside in this city. Most of the low-rise residential buildings of Dhaka city were converted into multi-storeyed apartment buildings and occupied around 50% of the ground area keeping rest for the purpose of vegetation. Later, this percentage of building footprint has increased from 50% to around 80% along with the practice of multi-storeyed housing or apartments to accommodate the surplus population in Dhaka city (Kamruzzaman & Ogura 2007; Nabi et al. 2004). At the end of the 1990s, apartments were built even on small plots almost without any setbacks or open spaces (Aziz & Kabir 2013). As a result, the city is losing its biodiversity, open space and interactive community spaces on the ground. Therefore, the concept of interaction among people in open spaces has gradually transformed within building or neighbourhood scale (Islam 2016) and rooftop has emerged as an interaction and breading space for the urbanites.

2.2 Use of rooftop space in different contexts

Types of rooftops and the usages of it differs from context to context due to diverse social, economic, and climatic needs like architecture. However, the excitement that evokes from the rooftop is a common aspect in all rooftop spaces and rooftop architecture around the globe. In the western part of the world the rooftop space is not used explicitly while in eastern part of the world (particularly in Asia) the usage of rooftop is comparatively extensive (Smetanina 2018).

Arguably, rooftop spaces are considered as an exclusive and privileged space in the western part of the world. Rooftop spaces are mostly used as rooftop gardens or green roofs which is also commonly known as 'rooftop architecture' in western countries. Apart of this, the rooftop is used to dump host unsightly technical utilities such as HVAC unit, antennas, piping, wires etc. which certainly reduces the appeal for using it for other purposes, hence, it is less utilized and often there is no access to the rooftop for common people (Smetanina 2018). Only this may be because of the rare use of rooftop in the west. On the contrary, in the east, rooftops are used more vibrantly. People reside in attics for their economic necessity to live closer

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Fig. 1 Rooftop became a place for social interaction amidst COVID-19 pandemic in Dhaka (Hossain 2020).

to the city with minimum house rent, increasing the use of rooftops, is a common scenario in Dhaka. Also, in Hongkong, informal rooftop communities are found (Smetanina 2018).

While accessibility and use of the rooftop as an interaction space are rare in western countries (Smetanina 2018), in Dhaka, many activities such as drying clothes, gossiping, and gardening are seen in the rooftops (Barua & Ikbal 2012; Iffat & Fatemi 2012), especially in the residential buildings, and it is open and accessible to its inhabitants. However, few residential rooftops are not permitted to be accessed by the apartment owner due to security and safety reasons. For example, buildings with low parapet height are not often accessible by all. Also, sometimes the owner uses the rooftop for vegetation and gardening, therefore, restricts apartment users to use it in fear of damaging and stealing of the plants and vegetables which is an unusual cause.

In most cases, the physical expressions are indispensably associated with the use of rooftop space. For example, an attached deck is typically used for drying clothes, vegetation and a net cover is used for the practice of different sports or to guard rooftop items from sturdy winds (Smetanina 2018). In Dhaka, the rooftops are accessible through the staircase inside buildings. From general field survey it has been observed that, while commercial buildings mostly use the rooftop for technical purposes (MEP, advertisement banner, Chiller, solar panels etc.) in apartment buildings, the rooftops are widely used for drying cloths, gossiping and vegetation. Rooftops in cities are now also used as a storage space, e.g., storing water drums, building materials.

2.3 Rooftop gardening and green roofs

The origin of green roof or rooftop gardening lies in the terrace garden from an ancient culture. The earliest known record of terrace gardens is the ancient Ziggurat from the city of Mesopotamia. Hanging garden of Babylon by King Nebuchadnezzar is another example of a terrace garden which is considered as one of the seven wonders from the ancient world (Cartwright 2018; Shimmin 2013). The formal definition of a rooftop garden perceives it as a technique of growing plants on the roof of a building by using containers (Daley 2015; Spacey 2017) whereas green roof is a technique of growing plants on the rooftop of a building over a protective waterproof membrane that separate hard roof from the soil (Rowe 2011; Spacey 2017). Nowadays, rooftops are considered as a part of urban landscape but most often these rooftops stay lifeless due to lack of greenery and vegetation on it (Thompson & Sorvig 2000). Hard rooftop surfaces also generate a lot of heat which restricts dwellers to use comfortably during daytime. Therefore, controlling micro-climate by reducing thermal heat through greening and vegetation is vital for transforming

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rooftop as an improved public space in densely urban cities like Dhaka.
Green roofs can be used for urban farming as well. Due to the issues of land scarcity, urbanization and poverty, small-scale urban farming or vegetation is getting popular in the cities (Barua & Ikbal 2012; Mesimaki et al. 2019). From general observation it seems that the urbanites of Dhaka cultivate various types of vegetables in their rooftops, particularly the ones which require less space and ground. However, this amount is not significant and there is not enough facility for renters to use the rooftop space for vegetation. Sometimes dwellers are not even allowed to use the space or enter the rooftop by the proprietor.

2.4 Uses of rooftop during COVID-19 pandemic

COVID-19 has halted people's daily activity and due to lockdown and quarantine measures people have nowhere to go but spend time in their apartments. Elders are seen passing leisure time, gossiping and enjoying fresh air on the rooftops while youths and children have made it their outdoor play area (Fig. 1). Few people have also adopted the habit of rooftop gardening to find peace in this COVID-19 crisis (Hossain 2020).
COVID-19 has definitely directly or indirectly influenced urbanites to use the rooftop more explicitly than ever. Table 1 summarizes different rooftop uses (mentioned above) based on the typology of rooftop with the inputs from above literatures and by adopting Smetanina (2018) for the residential and commercial context of Dhaka (Table 1). However, still, few rooftops are seen unoccupied or less vibrant. From the activity of people, it is hard to determine any specific features or typologies that are influencing people's presence and use of the rooftops. Therefore, finding variables that are affecting the usages of these rooftops need to be identified.
Table 1 with above literature indicates that there are some variables (rooftop typologies) which might influence the user activity in the rooftops. Basically, the percentage of those variables set a parameter of which rooftops are widely used by the residents and which are not. Therefore, following independent variables are assumed to have a correlation with rooftop activity numbers and between them hence all correlations are considered as alternative hypotheses. The selected independent variables here are:

1. Size of the rooftop (area),
2. Rooftop occupied by other services,
3. Parapet height,
4. Floor dampness (Dampness caused by leakage of water tanks and from rainfall),
5. Seating facility (nos.),
6. Gardening,
7. Comfort zone with pleasant view (%),
8. Safety (from falling down from rooftop). (%)

3 Methodology

This section describes the research approach that has been followed in this study. Both primary and secondary research methods have been followed to answer the research question through a correlational research approach. The correlational research has been followed to explore the correlation of diverse rooftop activities with different rooftop characteristics (independent variables) that might hinder use of the rooftop space. In doing so, qualitative and quantitative was collected through questionnaire survey and photographic observation. Prior to that literature review was conducted. Below is a brief description of the overall methodology.

3.1 Literature review

Initially, literature survey was conducted through Google Scholar search engine to address the problem statement and the research question. In doing so, academic peer reviewed journals, conference proceedings and open access articles were thoroughly studied. Google's default search engine was also searched as the authors did not find enough scholarly articles related to the uses of rooftop in Dhaka. This is one of the limitations of the study. Based on the research question the literature survey assisted to identify the rooftop as an interaction space with its various uses and find issues that are hampering the explicit use of rooftop in Dhaka. These literatures finally aided to identify the independent variables related to rooftop activities and the summary of uses and different types of rooftop activities which are presented in section 2.4 and table 1 respectively.
The review further assisted to guide the primary data collection method (photographic interview) and the data was focused on identifying both the independent and dependent variables related to types of rooftops and activity patterns of its users.

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Table 1 Summary of rooftop typology and its usage.

Rooftop Typology	Usage
Pitched or highly sloped roof	No utilization
Accessible flat rooftop with greening (less occupied by service functions)	Individual effort by residents to grow miscellaneous plants, trees, flowers, vegetables etc., gossiping, walking, sitting and drying cloths (mostly occupied). Advantages: Greening or green carpeting to cool down the rooftop surface and relaxation space for residents.
Accessible flat rooftop with custom structures e.g., pergola, shade and temporary or permanent pavilion.	Temporary structures used for the purpose of sitting, drying cloths, vegetation and often for beautification of the building. Also, few of these structures are used as BBQ party and marriage ceremony zone.
Occupied by solar panels and water tanks (both residential and commercial)	The rooftop surface hosts solar panels (a mandatory requirement for constructing building). Less vibrant, only used open portion of the rooftop for common uses like sitting, drying cloths etc.
Maximum portion of rooftop space engaged by Mechanical, Electrical and Plumbing equipment (mostly commercial)	Only used for maintaining service functions of the buildings.
Rooftops with advertisement banners (mostly commercial, few residential)	Commercial billboards occupying lessens the views and uses of it.
Not permitted by the owner to access to the rooftop	No utilization by tenants (only owner uses it for multipurpose use).
Accessible flat roof with net cover	Net cover attached or mounted to obstruct wind for sports purpose e.g., for playing badminton. Other uses: Aesthetic purpose, kite flying, and gossiping etc.

3.2 Data collection method

Primary data was collected by questionnaire survey through a convenience sampling method and interviewing selected respondents who were the students of architecture department of Stamford University, Bangladesh. Particularly these students were selected as they were trained with surveying techniques to observe the context rigorously. Initially, a questionnaire survey was circulated online among the students of the architecture department at Stamford University, Bangladesh. Among all the students, 12 students who reside in different areas of Dhaka city randomly responded to the survey. 1 respondent each from Rupnagar, Pirerbag, Dhanmondi, Rayer Bazar, Gandaria, Banasree, and Nakhalpara and 2 respondents from Hatirpool, and 3 respondents Mohammadpur sites were found (Fig. 2). The respondents were asked to observe the rooftops they are residing in for a week for 4 to 6 different times a day and capture photographs, take notes of the activities and physical attributes of the rooftops. Collecting information for a month or longer could have provided improved data but time limit was one of the limitations of the study (like convenience sampling) and the author decided to capture a week including weekend and weekdays to get an example of the overall scenario at the rooftop which only varies during festivals. A photographic interview method was applied to gather data. The interview questions were semi-structured (Supplement 1) and focused on measuring physical data (continuous) of the attributes and variables of the rooftops to use in identifying correlations. However, night-time data was not considered due to the restriction.

3.3 Correlation and significance test

After collecting all the data, correlational research was conducted. A correlational research strategy is suitable when the specific variables in question are measurable. Both the dependent and independent variables of the current study were measurable by indicators. The correlational conducted in this study was non-experimental (variables were not manipulated) and the data were collected through random naturalistic observation. Pearson correlational method was used to examine the strength and linear relationship between variables. Scatter plotting was done by Microsoft Excel software and calculation of correlation coefficient (r) and the value of P associated with r were statistically analyzed by SPSS software. Alternative hypothesises are assumed for all the correlations, therefore, there

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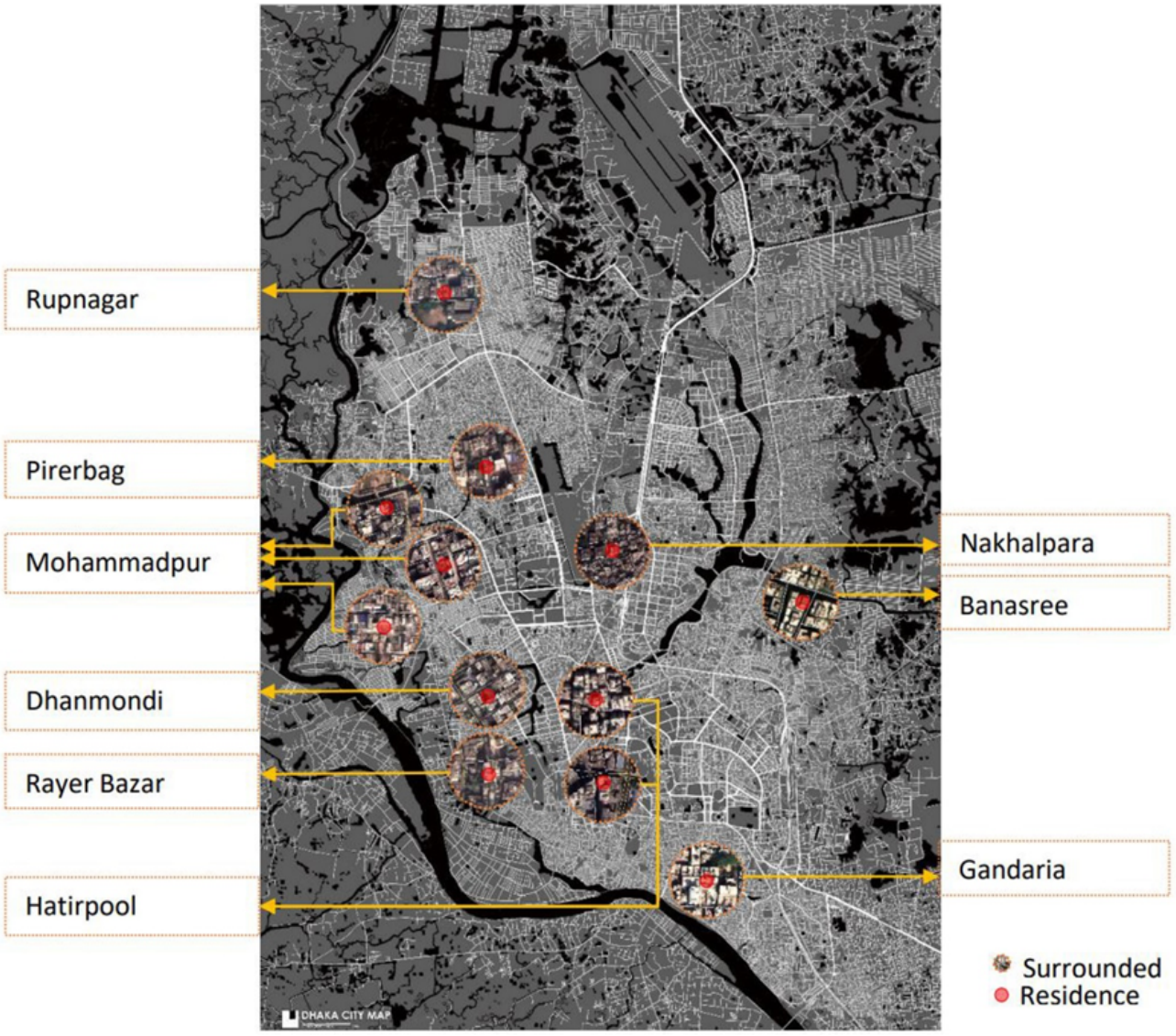


Fig. 2 Study area map with respondent's location (Source: illustrated from google map)

is a correlation between rooftop activity numbers with the independent variables.

Correlation coefficient (r) represents the correlation amongst two variables, a value measured between -1 and +1. In this study, the Pearson correlation coefficient (denoted as r which is the same as correlation coefficient) has been used to statistically calculate the strength and direction of the correlation among two variables. The greater the absolute value of r, the stronger the relationship among two variables. For Pearson correlation, the value of r, close to 1 indicates perfect to very high linear relationship among two variables and close to 0 indicates no linear correlation between two variables.

Table 2 Interpretation of correlation coefficient.

Correlation Strength	Degree of correlation
Perfect	± 1.00
Very high	± .90 to ± 1.00
High	± .70 to ± .90
Moderate	± .40 to ± .70
Low	± .20 to ± .40
Negligible	± .00 to ± .20

Positive and negative coefficient signs show the direction of the relationship.

If both variables increase or decrease together the coefficient is positive and the line represents the correlation slopes upward. If one variable tends

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to increase while the other decreases then r is negative and the line shows downward slope (Seigle 2015; Minitab 2019; Trochim 2021).
Table 2; is used in this study to interpret data which shows correlation values and subsequent patterns of strength and direction of the relationship among two variables.
A correlational research approach does not always imply causation. Having correlation does not always mean that one of them causes the other. A significance test can determine and assist to find true correlation among the variables. So, a significance test is conducted to determine the probability of the observed correlation occurring chance (Trochim 2021). In this research, alternative hypothesises are assumed between variables. So, if correlation between two variables is found ($r \neq 0$) then it will establish the alternative hypothesis and if no relationship between two variables ($r= 0$) is found then the alternative hypothesis will be rejected and the null hypothesis will be established.
In Pearson correlation coefficient (r) (used in the study) p-value indicates the significance level of the correlation of two variables and it can be positive or negative. In this study, the significance level (denoted as α or alpha) is considered 0.05 to test the significance level. If the p-value is equal or less than α then the correlation is statistically significant and there is conclusive evidence about the significance of the association among two variables. On the other hand, if the p-value is greater than α then the correlation is not statistically significant which means there is inconclusive evidence about significance of the association among two variables (Minitab 2019). Additionally, through a linear regression test the square of r is calculated to identify the amount of variation (Minitab 2019) explained by the correlation. As no strong prior theory was there to establish the correlation between the variables, a two-tailed test is conducted.

4 Analysis and Findings

4.1 Survey result

Table 3 shows results of 12 rooftops that were surveyed in this research. Size of the rooftops studied varied from approximately 2000 square feet to 6000 square feet. A range of activities e.g., walking, gossiping, drying clothes, seating, vegetation, playing, reading etc. were seen on different rooftops during different times of the day. Rooftop 12 was found to be the most vibrant place with the largest area (6000 square feet) where people gathered there for various types of activities (9 activities). On the other hand, rooftop 1, (2000 sq. ft.), rooftop 2 (2300 sq. ft.), rooftop 4 (4800 sq. ft.), rooftop 6 (3000 sq. ft.), and rooftop 8 (1650 sq. ft.) were found to be less vibrant with only one to two number of activities. From these statistics, no pattern of rooftop activity associated with the area of the rooftop was found.
Additionally, almost all the rooftops were found occupied by various service facilities such as water tanks, construction materials, and abandoned drums etc. which were presented as continuous data by calculating the service area's percentage in accordance with the total rooftop area. In the same way, floor dampness and gardening area were calculated. Gardening areas more than 30% (rooftop 3, 5, 9, 10, 11 and 12) have seating facilities while less than this percentage was found with no seating facility.
Parapet height of the rooftops ranged between 18 inches to 42 inches while only one rooftop's (rooftop 2) parapet height was found 3 inches. In terms of calculating safety, the respondents were asked to define a percentage of their feeling of safety on their rooftop. Respondents felt 0 percent safe on rooftops with 3 inches to 18 inches parapet height and 90 percent safe on rooftop with 42 inches parapet height. In the same way, respondents calculated the percentage of their comfort and pleasant view. It is found that rooftop no 3, 5, 7, 9, 10, 11 and 12 have a comfort zone with pleasant view percentage of 50% to 90%, gardening facility of more than 20% and seating facility and floor dampness of less than 10%. However, among these seven rooftops, rooftop 7 has its 30% area occupied by different services, and has a comfort and pleasant view of 50%.
Above result shows that there is a relationship between different variables. While in a few cases clear patterns between two variables were seen, few cases were not clearly associated, and anomalies were found. Hence, results of correlation with significance tests were initiated to assist, justify, and establish any true relation, if there is any, between different variables.

4.2 Correlation result of independent variables with the number of rooftop activity

This section shows the results of correlations found through SPSS analysis. Also, the scatter plots (found through linear regression model in Microsoft Excel) of the correlations are presented here (Fig. 3) which assisted in the interpretation of the results.

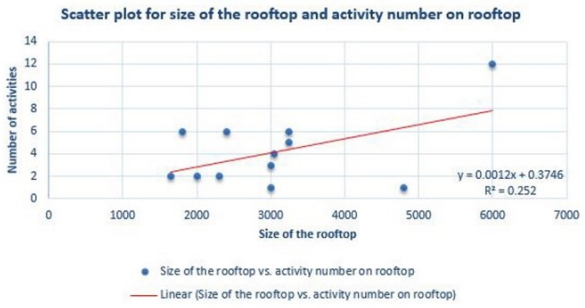
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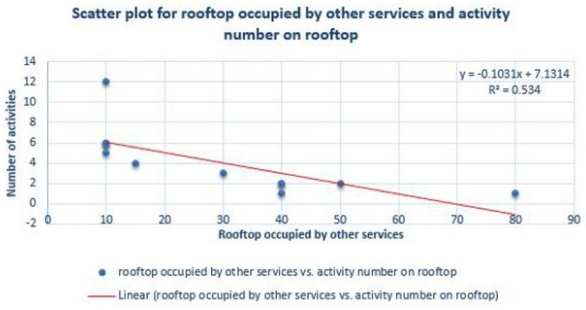
Table 3 Survey results

Rooftops	Name and number of activities	Size (area) of the rooftop (sq. ft. approx.)	Rooftop occupied by various services (%)	Parapet height (inch.)	Floor dampness (%)	Seating facility (nos.)	Gard. (%)	Comfort zone with pleasant view (%)	Safety (%)
Rooftop 01	Walking, gossiping (2)	2300	50	18	80	00	00	20	00
Rooftop 02	Walking, drying cloth (2)	2000	40	3	20	00	00	40	10
Rooftop 03	Drying cloth, seating, gossiping, walking, vegetation (5)	3250	10	34	00	02	35	70	50
Rooftop 04	Drying cloth (1)	4800	40	3	80	00	00	10	00
Rooftop 05	Drying cloth, seating, vegetation, gossiping, exercise, walking (6)	2400	10	36	00	02	30	70	70
Rooftop 06	Walking (1)	3000	80	24	90	00	00	30	10
Rooftop 07	Vegetation, gossiping, walking (3)	3000	30	24	40	00	20	50	35
Rooftop 08	Gossiping, vegetation (2)	1650	40	30	50	00	10	30	30
Rooftop 09	Barbeque party, gossiping, drying cloth, walking, seating, vegetation (6)	3250	10	36	10	03	25	60	70
Rooftop 10	Gossiping, playing, walking, vegetation, seating, drying cloth (6)	1800	10	33	10	03	30	70	70
Rooftop 11	Seating, drying cloth, walking, vegetation (4)	3050	15	36	10	02	30	60	80
Rooftop 12	Barbeque party, reading, vegetation, playing, exercise, gossiping, walking, drying cloth, seating (9)	6000	10	42	00	08	40	90	90

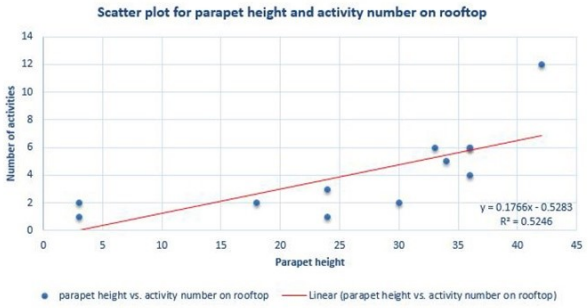
Gard. - Gardening



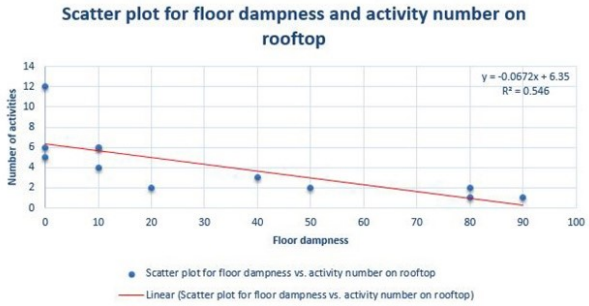
(a)



(b)



(c)



(d)

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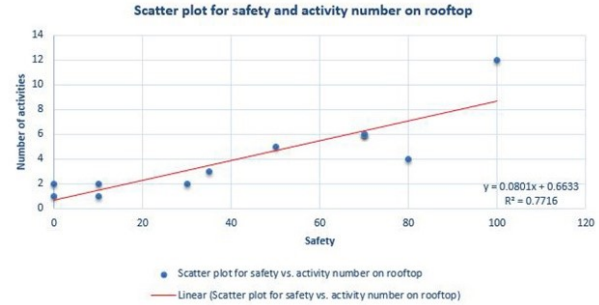
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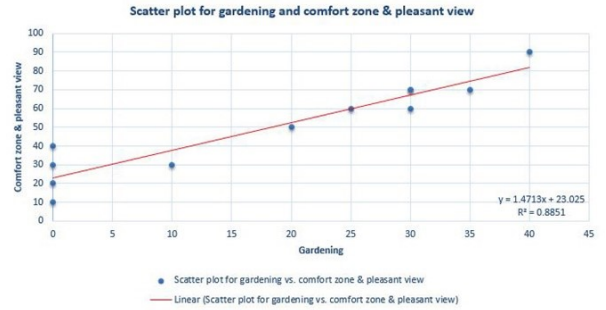
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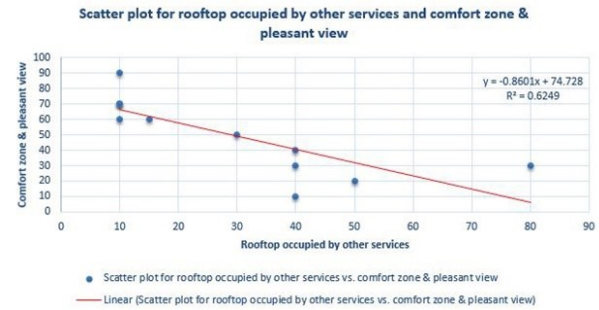
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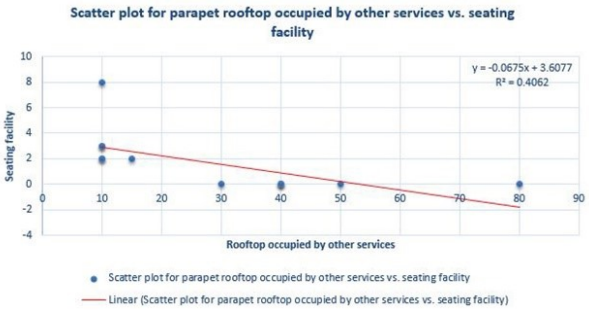
(i)



(j)



(k)



(l)

Fig. 3 Scatter plots of the correlations

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The authors assume there are alternative correlations between the number of rooftop activities and all other variables. Table 4 demonstrates these correlations which are described below.

4.2.1 Correlation between size of the rooftop and number of activities

Pearson correlation coefficient between size of the rooftop and number of activities was found to have a (R = 0.372, p = 0.234) low positive linear and statistically not significant correlation at the significance level of 0.05. This means there is inconclusive evidence about the significance of the relationship. This rejects the alternative hypothesis (Fig. 3a; Table 4) and establishes a null hypothesis that there is no linear correlation between these two variables. Also, R2 = 0.14 means 0.14% variability in size of the rooftop is explained by the variability in number of activities and the other 99.86% of variance is dependent by unknown factors or unknown variables. Therefore it can be concluded that number of rooftop activities does not rely on the size of the rooftop.

4.2.2 Correlation between rooftop occupied by various services and number of activities

Pearson correlation coefficient between rooftop occupied by various services and number of activities was found to have a (R = -0.821, p = 0.001) highly negative linear and statistically significant correlation at the significance level of 0.05. This means there is conclusive evidence about the significance of the relationship. This supports the alternative hypothesis (Fig. 3b; Table 4) that there is linear correlation between these two variables. However, R2 = 0.67 which means 67% variability in seating facility is explained by the variability in number of activities and the other 33% of variance is dependent by unknown factors or unknown variables.

4.2.3 Correlation between parapet height and number of activities

Pearson correlation coefficient between parapet height and number of activities was found to have a (R = 0.774, p = 0.003) highly positive linear and statistically significant correlation at the significance level of 0.05. This means there is conclusive evidence about the significance of the relationship. This supports the alternative hypothesis (Fig. 3c; Table 4) that there is linear correlation between these two variables. However, R2 = 0.60 which means 60% variability in seating facility is explained by the variability in number of activities and the other 40% of variance is dependent by unknown factors or unknown variables.

4.2.4 Correlation between floor dampness and number of activities

Pearson correlation coefficient between floor dampness and number of activities was found to have a (R = -0.821, p = 0.001) highly negative linear and statistically significant correlation at the significance level of 0.05. This means there is conclusive evidence about the significance of the relationship. This supports the alternative hypothesis (Fig. 3d; Table 4) that there is linear correlation between these two variables. However, R2 = 0.67 which means 67% variability in seating facility is explained by the variability in number of activities and the other 33% of variance is dependent by unknown factors or unknown variables.

4.2.5 Correlation between seating facility and number of activities

Pearson correlation coefficient between seating facility and number of activities was found to have a (R = 0.923, p <0.001) very highly positive linear and statistically significant correlation at the significance level of 0.05. This means there is conclusive evidence about the significance of the relationship. This supports the alternative hypothesis (Fig. 3e; Table 4) that there is linear correlation between these two variables. However, R2 = 0.85 which means 8% variability in seating facility is explained by the variability in number of activities and the other 15% of variance is dependent by unknown factors or unknown variables.

4.2.6 Correlation between gardening and number of activities

Pearson correlation coefficient between gardening and number of activities was found to have a (R = 0.903, p <.001) very highly positive linear and statistically significant correlation at the significance level of 0.05. This means there is conclusive evidence about the significance of the relationship. This supports the alternative hypothesis (Fig. 3f; Table 4) that there is positive linear correlation between these two variables. However, R2 = 0.82 which means 82% variability in seating facility is explained by the variability in number of activities and the other 18% of variance is dependent by unknown factors or unknown variables.

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Table 4 Result of Correlations

Variables		Number of activities	Size of the rooftop	Rooftop occupied by other services	Parapet height	Floor dampness	Seating facility	Gardening	Comfort zone with pleasant view	Safety
Number of activities	Pearson Correlation	1	0.372	-0.821**	0.774**	-0.821**	0.923**	0.903**	0.934**	0.919**
	Sig. (2-tailed)		0.234	0.001	0.003	0.001	0.001	0.001	0.001	0.001
Size of the rooftop	Pearson Correlation	0.372	1	-0.175	0.113	-0.052	0.606*	0.280	0.233	0.285
	Sig. (2-tailed)	0.234		0.587	0.726	0.873	0.037	0.378	0.465	0.369
Rooftop occupied by other services	Pearson Correlation	-0.821**	-0.175	1	-0.588*	0.898**	-0.637*	-0.871**	-0.791**	-0.818**
	Sig. (2-tailed)	0.001	0.587		0.044	0.001	0.026	0.001	0.002	0.001
Parapet height	Pearson Correlation	0.774**	0.113	-0.588*	1	-0.609*	0.674*	0.851**	0.790**	0.864**
	Sig. (2-tailed)	0.003	0.726	0.044		0.036	0.016	0.001	0.002	0.001
Floor dampness	Pearson Correlation	-0.821**	-0.052	0.898**	-0.609*	1	-0.641*	-0.856**	-0.898**	-0.836**
	Sig. (2-tailed)	0.001	0.873	0.001	0.036		0.025	0.001	0.001	0.001
Seating facility	Pearson Correlation	0.923**	0.606*	-0.637*	0.674*	-0.641*	1	0.774**	0.818**	0.840**
	Sig. (2-tailed)	0.001	0.037	0.026	0.016	0.025		0.003	0.001	0.001
Gardening	Pearson Correlation	0.903**	0.280	-0.871**	0.851**	-0.856**	0.774**	1	0.941**	0.940**
	Sig. (2-tailed)	0.001	0.378	0.001	0.001	0.001	0.003		0.001	0.001
Comfort zone with pleasant view	Pearson Correlation	0.934**	0.233	-0.791**	0.790**	-0.898**	0.818**	0.941**	1	0.922**
	Sig. (2-tailed)	0.001	0.465	0.002	0.002	0.001	0.001	0.001		0.001
Safety	Pearson Correlation	0.919**	0.285	-0.818**	0.864**	-0.836**	0.840**	0.940**	0.922**	1
	Sig. (2-tailed)	0.001	0.369	0.001	0.001	0.001	0.001	0.001	0.001	

4.2.7 Correlation between comfort zone with pleasant view and number of activities

Pearson correlation coefficient between comfort zone with pleasant view and number of activities was found to have a (R = 0.934, p <.001) very highly positive linear and statistically significant correlation at the significance level of 0.05. This means there is conclusive evidence about the significance of the relationship. This supports the alternative hypothesis (Fig. 3g; Table 4) that there is linear correlation between these two variables. However, R2 = 0.87 which means 87% variability in seating facility is explained by the variability in number of activities and the other 13% of variance is dependent by unknown factors or unknown variables.

4.2.8 Correlation between safety and number of activities

Pearson correlation coefficient between safety and number of activities was found to have a (R = 0.919, p <.001) very highly positive linear and statistically significant correlation at the significance level of 0.05. This means there is conclusive evidence about the significance of the relationship. This supports the alternative hypothesis (Fig. 3h; Table 4) that there is linear correlation between these two variables. However, R2 = 0.84 which means 84% variability in seating facility is explained by the variability in number of activities and the other 16% of variance is dependent by unknown factors or unknown variables.

4.3 Other correlations

Due to the scope of the work not all correlations among the variables were analyzed. As the study focuses on finding correlations between different rooftop types and rooftop activity, associated alternative hypothesises (except number of activities) are tested and presented in this section. The authors assume there are correlations among the following variables.

4.3.1 Correlation between rooftop occupied by various services and Comfort zone with pleasant view

Pearson correlation coefficient between rooftop occupied by various services and Comfort zone with pleasant view was found to have a (R = -0.791,

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p = 0.002) highly negative linear and statistically significant correlation at the significance level of 0.05. This means there is conclusive evidence about the significance of the relationship. This supports the alternative hypothesis (Fig. 3i; Table 4) that there is linear correlation between these two variables. However, R2 = 0.63 which means 63% variability in rooftop occupied by various services is explained by the variability in comfort zone with pleasant view and the other 37% of variance is dependent by unknown factors or unknown variables.

4.3.2 Correlation between gardening and Comfort zone with pleasant view

Pearson correlation coefficient between gardening and comfort zone with pleasant view was found to have a (R = 0.941, p <.001) very highly positive linear and statistically significant correlation at the significance level of 0.05. This means there is conclusive evidence about the significance of the relationship. This supports the alternative hypothesis (Fig. 3j; Table 4) that there is linear correlation between these two variables. However, R2 = 0.89 which means 89% variability in gardening is explained by the variability in the comfort zone with pleasant views and the other 11% of variance is dependent by unknown factors or unknown variables.

4.3.3 Correlation between parapet height and safety

Pearson correlation coefficient between parapet height and safety was found to have a (R = 0.864, p <.001) highly positive linear and statistically significant correlation at the significance level of 0.05. This means there is conclusive evidence about the significance of the relationship. This supports the alternative hypothesis (Fig. 3k; Table 4) that there is linear correlation between these two variables. However, R2 = 0.75 which means 75% variability in parapet height is explained by the variability in safety and the other 25% of variance is dependent by unknown factors or unknown variables.

4.3.4 Correlation between rooftop occupied by other services and seating facility

Pearson correlation coefficient between occupied by other services and seating facility was found to have a (R = 0.64, p =.001) moderately negative linear and statistically significant correlation at the significance level of 0.05. This means there is conclusive evidence about the significance of the relationship. This supports the alternative hypothesis (Fig. 3l; Table 4) that there is linear correlation between these two variables. However, R2 = 0.41 which means 41% variability in rooftop occupied by other services is explained by the variability in number of activities and the other 59% of variance is dependent by unknown factors or unknown variables.

5 Discussion

Since the correlation result only provides the value of coefficient and the strength of relationship, predictions against the causes and the consequences must be defined from the analysis (Husin et al. 2015). From the result, it is seen that all the alternative hypothesises are established except one. While the strength of relationship between variables is found through correlation, analysing the regression analysis, scatter plot, significance test and Table 4, the authors predict the below cause-and-effect relationship,

- There is no correlation between the size and number of activities occurring on a rooftop. If the size of the rooftop increases or decreases, it will not have any effect on the number of activities. It is also seen (table 4) that, with the increase or decrease of the area of the rooftop, could not discourage people from coming to the rooftop.
- There are highly negative linear and statistically significant correlation between,
  - rooftop occupied by various services and number of activities,
  - floor dampness and number of activities, and
  - the rooftop is occupied by various services and a comfort zone with a pleasant view.

So, the more the area of the rooftop will be occupied by various services, the less the number of activities will be and the comfort zone with pleasant view will also decrease. Similarly, if floor dampness increases the number of activities will decrease and vice-versa. In all cases, there is around 75% probability that this will happen. Similarly, occupying rooftop areas with services e.g., drums, construction materials etc. will impede users to walk around and enjoy the pleasant views around which will ultimately reduce use's appearance of the rooftop. However,

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floor dampness will not affect the number of activities during the dry season as this situation mostly occurs during the rainy season.

- There are highly positive linear and statistically significant correlation between,
  - parapet height and number of activities, and
  - parapet height and safety.

So, it is evident that if the parapet height increases the number of activities will increase as well as the feeling of safety among its users. There is 75% probability that parapet height increases, the safety will increase and 60% probability that if the parapet height increases the number of activities will increase and vice-versa. However, this does not mean parapet height can be excessive, for example 10 feet or higher parapet height will obviously block users view, generate unwanted space for its users and will ultimately reduce user activity. The height might also be determined by depending on the height of the building. The alarming fact is that there are buildings with very low parapet height which might cause dangerous situations, even death. This is because of violation of building rules rather than a limited vision of architects.

- There are very highly positive linear and statistically significant correlation between,
  - seating facility and number of activities,
  - gardening and number of activities,
  - comfort zone with pleasant view and number of activities,
  - safety and number of activities, and
  - gardening and comfort zone with pleasant view.

So, there is a very high probability (around 85% for these 5 cases) that with increase in seating facility, gardening, safety and comfort zone with pleasant views, the number of activities will increase and vice-versa. Similarly, if gardening is increased the comfort zone with pleasant view will increase significantly and vice-versa. These variables also complement each other. For example, an increased seating facility will provide more people to sit and hence increase user's number at a time, more gardening facilities will attract more users to avail this facility, and hence it will improve comfort zone and pleasant views which will encourage more people to gather on the rooftop.
Therefore, if the rooftop is to be used more and developed as an improved social and recreational interaction space, above variables can be used as an indicator. These independent variables are important for rooftop design and because they affect the use of particular rooftops. Another important conclusion is that green roofs were not found on these 12 rooftops.
Although the studied variables are changing the number of activities on rooftops, for finding accurate output the sample size needs to be increased. Additionally, all the activities mentioned here were observed for a week, which, if observed for a month the chances of accurate value of data would have been greater. Also, this study does not consider night-time activities due to several limitations such as restriction to access to the rooftop during night.

6 Recommendation and Conclusion

A growing city like Dhaka while the land and space are increasing rapidly, the maximum priority should be given to the maximum use of all spaces. As the rooftop is an essential part of our residence, this space's physical and metaphysical uses also need to be reconsidered and prioritized. According to the analysis and study it could be recommended to:

- Provide seating and gardening facilities as much as possible.
- Maintain proper parapet height as per building design guideline.
- Separate or hide service functions in a way that it does not hamper user's view and activity.
- Some rooftops are not commonly used by users due to damp floor conditions and being occupied by other services, it is recommended to ensure user accessibility so that they may enhance their involvement to reduce such condition through different activities
- Rooftops need to have proper waterproofing to protect it from dampness and restrict the growth of algae.
- Ensure safety for everyone constructing proper parapet height.
- Idea of a green rooftop should be promoted widely for creating sustainable built environment.

Designing buildings considering these variables would be the recommended solution of this research

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which will accelerate the use of such highly valued space in modern residential apartment buildings. Although some of these attributes or variables are currently available in rooftops, most of these are not consciously designed considering spatial, social or recreational perspectives of rooftop architecture. Therefore, limited benefits and opportunities are being experienced by its users. The concept of rooftop architecture needs more study for improving its use in a dense city like Dhaka. Along with providing the recommended solutions the study suggests exploring further roofscape connections with adjacent buildings and design it considering social, environmental and recreational perspectives. This is now a mandatory need for the urbanites in the crisis of open green space within proximity. This research shows related aspects or characteristics of rooftops that need to be improved or increased in order to develop rooftops as an improved vibrant social and recreational space. This will assist and guide architects to design residential building's rooftop and understand the behaviour of users that impact their activity on rooftop. Therefore, architects will be able to provide proper design elements and contribute to the development of robust social and recreational space at residential rooftop which certainly could be a noble finding in the verge of global pandemics like COVID-19 and reduced green open spaces in compact urban areas, where rooftops are becoming the only space to meet the social and recreational need of the urbanites. Although this research studies a specific compact urban environment the findings of this study can be used in cities going through urban consolidation process. Adding these considerations in designing apartment buildings would certainly improve overall biodiversity, amenity and diversity of the cities.

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Supplement 1: Questionnaire for the survey after a week of observation

1) What is the size (area) of the rooftop?
2) What type of activities are occurring on the rooftop?
3) How many activities are happening on the rooftop?
4) How much space of rooftop is occupied by other services? (Percentage: 0-100%)
5) What is the parapet height?
6) How much damp floor is on the rooftop? (Percentage: 0-100%)
7) How many seatings (fixed or portable) are in the rooftop?
8) How much area on the rooftop is covered by gardening? (Percentage: 0-100%)
9) What is the level of comfort zone with pleasant view? (Percentage: 0-100%)