Policy Brief

ADOPTION OF A PERFORMANCE EVALUATION TECHNIQUE FOR THE DEVELOPMENT OF A FRAMEWORK FOR THE CLIMATIC RESPONSIVE URBAN DESIGN (CRUD)

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INTRODUCTION

The mass influx/migration of human population from ruler area and resulting changes in urbansettings is known as urbanization. A significant increase in the percentage of the world population living in urban areas has been observed over the past few decades. As per the UnitedNation's updated estimates for the year 2018, 55% of the world's population was living in urbanareas and is expected to increase to 68% by 2050. A similar steady trend in the growth rate of the urban population has been observed in the case of Pakistan. In 2019, the annual percentagegrowth in the urban population was around 2.7%.

Although urbanization is mostly considered as an indicator of economic, social, and political progress of a society, it can also lead to several challenges including urban sprawl, environmental and health issues, increasing crime and human insecurity related problems, poorurban governance, weak financial capacity of cities and higher living cost, etc. Urban areas havesignificant energy consumption and CO2 emissions footprint. The negative impacts of rapid urbanization on the environment are profound and reach far beyond urban settlements themselves. Environmental degradation in urban areas is a serious developmental issue in Pakistan. A slight glance at the annual mean temperature, sea level, and rainfall patterns is ampleto portend the looming crisis.

The goal of this research is to guide the designer for the early-stage climate responsive urban design. The impact of different urban design elements i.e. street canyon geometry (Canyon length, width, height, orientation, and SVF) and greenery have been evaluated on the urban microclimate which affects the energy load and thermal comfort in the built environment.

METHODOLOGY

Land Cover and Land Use Classification Map of Study Area

The present study was carried out in Islamabad (planned) and Rawalpindi (semi-planned) located at 33.662883° Lat, 73.086373°Lon. The concept of Local Climate Zone (LCZ) is used to prepare Land Use and Land Cover (LULC) maps of the Twin cities.

Remote-Sensing (RS) based Assessment of Urban Microclimate

In the present study, the freely available satellite (LANDSAT 8) images have been used for the retrieval of LST. The Landsat-8 imagery of Twin cities was acquired at 05:42 UTC (about 10:42am local standard time) on July 02, 2021).

Computational Fluid Dynamics Based Assessment of Urban Microclimate

In the present study, urban flow simulations have been performed using Envi-met software. TheENVI-met study areas of the twin cities are shown in Figure 3. AutoCAD is used to delineate building features in the imagery for the generation of 3D models (as shown in Figure 4). The simulations are performed for 10^{th} June 2021, the hottest day of summer (for year 2021) with the highest temperature of 43^{o} c in the afternoon.

RESULTS AND DISCUSSIONS

Effect of Urban Design Elements on Microclimate

Relationship between the LST and urban design variables

To evaluate the relationship between the LST and different street canyon geometry variables (Canyon length, width, height, orientation, and SVF), around 80 different street canyons of Islamabad and Rawalpindi have been selected. The LST values inside this street canyon are extracted from the LST map of twin cities. The following regression models have been fitted between the dependent and independent variables using the response surface-based method.

Table 1: Coefficients of the estimated regression model for Islamabad with standard errors and t-value

Coefficients	Estimates	SE (Coefficient)	t- value	p-value
Constant	29.0734	0.8684	33.479	0
Canyon Orientation	-0.0054	0.00086	-6.267	0
SVF	6.9123	1.3095	5.279	0
Canyon Width	0.6721	0.08283	8.114	0
Canyon Height	-0.0482	0.0185	-2.604	0.011
Canyon Length	-0.0004	0.00068	-0.568	0.572
SVF*Canyon Width	-0.8601	0.11655	-7.38	0
R-Sq = 71.83%, R-Sq(pred) = 65.00%, R-Sq(adj) =69.38%				
Note: SE (coefficients) is the standard error of coefficients				

Table 2: Analysis of Variance

Source	Degree of freedom	Sum of square	Mean Square	F-ratio	P-value
Regression	6	15.5447	2.59079	29.32	0.000
Error	69	6.0972	0.08837		
Total	75	21.6420			

Table 3: Coefficients of the estimated regression model for Rawalpindi with standard errors and t-value

Coefficients	Estimates	SE (Coefficient)	t- value	p-value
Constant	34.3698	0.23495	146.283	0
Greenery Index	-6.0736	2.65306	-2.289	0.025
SVF	2.4011	0.91689	2.619	0.011
Canyon Width	0.0568	0.04280	1.327	0.188
Canyon Height	-0.0486	0.01134	-4.290	0
Canyon Orientation	0.004	0.00022	1.969	0.052
Canyon Length	-0.0028	0.00073	-3.837	0
SVF*Canyon Width	-0.3190	0.15308	-2.084	0.040
R-Sq = 47.61% R-Sq(pred) 38.64%, R Sq(adj)= 42.97% Note: SE (coefficients) is the standard error of coefficients				

Table 4: Analysis of Variance

Source	Degree of freedom	Sum of square	Mean Square	F-ratio	P-value
Regression	7	2.83829	0.405469	10.26	0.000
Error	79	3.12304	0.039532		
Total	86	5.96133			

CONCLUSIONS AND POLICY RECOMMENDATIONS

The important conclusion derived from the current research can be used by designers for climate-responsive urban design in case of the future extension of these cities. The important results of the current research are

1. Being highly urbanized regions, most of the urban areas in twin cities are associatedwith high LST.

2. According to the regression analysis result, canyon height, width, length and orientationhave a significant correlation with LST. The Skyview factor is has a significant positive correlation with LST in both cities. So by decreasing Skyview factors either by (i) introducing the deep street canyons or (i) increasing the greenery inside the wide canyon will reduce the LST intensity inside these street canyons.

3. According to the CFD simulation results,

a. The intensity of shortwave radiation decreases with an increase in H/W ratios

b. An inverse relation between the air temperature and the H/W ratio can be observed for both cities. A reduction of 2.1^0 C and 4^0 C in the peak air temperaturehas been observed due to the increase in H/W ratios in the case of Islamabad andRawalpindi, respectively.

c. In the case of Islamabad, street canyons oriented in the NE-SW direction are slightly warmer than NW-SE oriented canyons. Similarly, in the case of Rawalpindi, irrespective of the H/W ratio, the street canyons oriented in the E-Wdirection are warmer than canyons oriented in other directions (N-S and NE-SW)

d. For both cities i.e. Islamabad and Rawalpindi, Tmrt has relatively low values in thedeep street canyons.

e. In the case of Islamabad and Rawalpindi, a reduction of 2.3^{0}C and 4.6^{0}C respectively in PET peak values has been noticed due to the increase in H/W ratios.

f. In the case of Islamabad, NE-SW streets are up to 7.5 °C (on PET scale) warmer than NW-SE streets during peak PET times. Similarly, in the case of Rawalpindi, E-W streets having H/W= 0.73 are up to 5.15 °C (on PET scale) warmer than N-S streets during peak PET times.

g. However, a significant reduction in the PET intensity has been observed in the vicinity of trees. Thus, the thermal performance of a street canyon can be improved by increasing the tree coverage of these streets

Policy Recommendations

1. The instant study underscores the significance of altering the contemporary regulations and bylaws to encourage more efficient layouts and elevations - such as vertical construction.

2. The magnitude of the impact of different urban design variables on urban microclimate, and outdoor comfort may vary from city to city, an appropriate scientific intervention ought to be followed at the very inception stage to ensure a climate-responsive urban planning and design.