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RESEARCH PAPER

General Architecture

Comparative Study of Shading Effect of Built Environment on Thermal Comfort in Two Campuses of Tehran

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Abstract

Outdoor spaces and their thermal condition is becoming a controversial issue in modern architecture and urbanism. It has a great effect on people who use the open spaces like campuses where many students from different cities spend most of their time. This research investigated the effect of SVF, MRT and PET in the two campuses namely: Iran University of Science and Technology (IUST) and Amirkabir University of Technology (AUT). Thermal condition of campuses has diverse states due to their different level of shaded open spaces. PET is calculated via Rayman for thermal-comfort assessment in spring and summer, 2015. Subsequently, it was determined that by decreasing SVF to 0.4, Tmrt declines to 3.04°C. The variations of MRT's influence PETs drop. PET comparison in two campuses illustrates that in an average value of PET, there is 0.86°C dissimilarity between campuses in the warmest time of the year (July). IUST campus is 1.39°C cooler on the PET measure. In conclusion, increasing shaded spaces by increasing green spaces and trees can create cooler campuses. Integrated design of shaded open spaces with their architectural forms is recommended as a design strategy for the designers to create a responsive environment in terms of thermal comfort. By this means, cooler campuses are more prone to be used by students and their activities.

Keywords: *University campuses, Shaded open spaces, Thermal comfort, SVF, Tmrt, PET.*

1. INTRODUCTION

The microclimate of the built environment is dominantly affected by the physical urban elements such as building block, greenery, etc. Urban Heat Island (UHI) is a common phenome which is directly influenced by the mentioned parameters [1-2]. Campuses generally act like urban in microscale [3]. Campus and its surrounded blocks significantly affect their climatic environment much more than the inner environment of universities themselves. The campuses are not used only for educational purposes but many cultural and social activities are occurring in the outdoor environment of universities [4].

Being thermally comfortable is of the many factors touching the quality of the events in campuses. The outdoor thermal-comfort state of the public spaces is an important concern that influences the quality of outside events. This kind of comfortability is a generally unknown and neglected area of research. Thermal comfort is usually defined as that condition of mind which expresses satisfaction with the thermal environment [5]. Outdoor thermal comfort is an integrated concept containing both physical and mental perception [6].

This complicated concept is generally influenced by many parameters such as façade materials, blocks enclosure, density of green spaces, etc. Because of severe sun radiation, high Ta happens during summer and sometimes in spring and heat stress condition happens in these days. Discomfortable condition can be alleviated by shaded open spaces by blocking solar radiation and decreasing the radiation absorption by surfaces [7]. Environment enclosure is defined as a technical idea named "Sky View Factor". SVF is defined as “the ratio of the amount of the sky which can be seen from a given point on a surface to that potentially available part (i.e., the sky hemisphere subtended by a horizontal surface)” [8]. This concept affects many scientific parameters such as thermal indices. Therefore, in this particular study, the PET as the main thermal index of outdoor thermal comfort will be analyzed through the SVF variable. The present research attempted to demonstrate the role of shaded outdoor areas in the outdoor thermal-comfort with the

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most applicable thermal index namely PET; thus, the findings contribute the designers' insight about creating shaded places to increase the thermal quality of outdoor settings. The present investigation was carried out in the spring and summer of 2015 but fall and winter can be also taken into account and this is suggested for future studies.

1.1. Literature review

In the past studies, the lower time air temperature and higher night temperature are reported as final results of high enclosure environment [9-15]. Hwang, Lin, and Matzarakis, have carried out a study titled "Seasonal effects of urban street shading on long-term outdoor thermal comfort". The results showed that relatively shady areas are usually very hot during summer, especially at noon. However, very shady areas usually have the same physiological temperature during the winter (PET). The analysis of the relationship demonstrations that thermal-comfort is well when a site spans the shadow throughout spring, summer and fall. During winter, low shade conditions may help increase sun radiation; as a result, thermal comfort improves when a place has a shadow in the winter. They recommended that a cool surface is enhanced for urban roads and shrubberies or shading strategies can be implicated to develop the novel thermal environment. [16]. There are studies that presented a close association between Ta and SVF [17-19] and the weak correlation is reported too [20-22]. The effect of urban-geometry on thermal comfort using virtual simulation in Brazil by Krüger, Minella, Rasia in 2011, demonstrated that the relationship between built-up geometry and variations in air-quality in the town center is a high correlation. Two methods are offered that show the consequences of experimental results and urban weather simulations using the Envi-met software. Using micron-climatic measurements and comfort examinations, in the center of Curitiba, Brazil, the effect of street physical structure on ambient Ta and day-passers comfort was assessed using the SVF as a pointer of the complexity of urban geometry. The outcomes of street direction on dominant-winds and air-conditioning condition (air velocity and spatial distribution) were studied on the scattering of air-pollutants generated by virtual simulations. Eventually, the authors showed the impact of urban-geometry on the human thermal sensation on the sidewalks and the results of emission circumstances [23]. Some studies have reported a high correlation net measured longwave and Sky View Factor. The field measured illustrated that environmental enclosure itself is not only an effective parameter [24-25]. Tianyan et al. (2012) have carried out a study titled "campus clusters in subtropical areas". In this research, they examined the impact of various types of design factors on the open setting surroundings area of the site in semi-tropical areas. They then directed a study using a questionnaire on the thermal feeling and comfort in academic clusters to study the mental responses of young pupils to the environment in urban areas. The assessment of thermal-comfort by the SET index expressed that the neutral SET of students is 24°C. The dissimilarity between the Ta of 9K among the building blocks and a lawn-covered area is expressed, that shows the effect of the SVF on ground heat and Ta distribution of the air at night time. Due to the great SVF, short wave reflections and long wave wavelengths occur in the field: attention should be paid to the fact that a very hot open space area can be created over the day. With the impact of the Mmean radiant Ta, the SET of educational blocks is more than the average squares and pilots in the afternoon, which is expected to reduce the permissible level of outdoor thermal space. Pilotis can be reduced from 6 to 10 ° C; therefore, pilotis is encouraged to create an outdoor thermal environment in sub-tropical cities [26]. Heat stress as a final result of high Ta and exposed sky regarding mean radiant temperature (Tmrt) has been investigated in urban parks [27]. Campuses of IUST and AUT with the dissimilar condition of built setting contain the dissimilar thermal surrounding area. Recently, some studies were done regarding the shading influence on thermal sensation [28-33]. Many thermal indices like PET are affected by solar radiations as the main factor of heat stress [34-39]. Mean Radiation Temperature has been investigated by some research in campuses [40-42]. Tleghani et al. (2014) have done a study titled "Thermal assessment of heat mitigation strategies: The case of Portland State University, Oregon, USA". This study was conducted during the summer in the moderate environment of Portland, Oregon. Compared to the seven campuses, the utmost impact on the 8.8 ° C cooling green areas was between the parks' lot and the roadside parking portion. The simulations of the gardens with greeneries and pools showed 1.6 ° C and 1.1 ° C, respectively. The reversal of the pavers in an unfilled yard from 0.37 (black) to 0.91 (white) caused an average increase in MRT and a Ta drop of 1.3 ° C [43]. The thermal-comfort of the shaded open areas by Lin et al. was reviewed in 2010. This study carried out 12 field tests to analyze the temperature conditions at the university campus in central Taiwan and used the RayMan model to forecast the long-term thermal-comfort of using weather data for a 10-year period. PET is used as a thermal pointer. The findings demonstrated that the SVF, which represents the proportion of SVF in certain locations, meaningfully affects outdoor areas. Analytical results showed that a high (slightly shaded) SVF creates summer discomfort and a low tilt (strongly shaded) causes discomfort in the winter time. As Taiwan has warm and mild winters, shadows should be provided by trees and buildings to improve the comfort of the summer. However, since Taiwan has a weak tolerance for cold weather, space-based space planning should prevent the creation of areas with too much shadow. Therefore, the thermal requirements of residents and local weather characteristics should be considered when creating outdoor spaces in the open air [44]. There are few studies in Iran which are associated with the outdoor-thermal-comfort [45-49]. Ghazizadeh et al. (2012) suggested some strategies by virtual technique to arrange outdoor places much comfortable. Consequently, the authors represented the built-up areas in dissimilar locations to reach the finest thermal circumstances from the point of view Tmrt, SVF, shaded open spaces [50]. Heidari et al. (2013) have compared diverse thermal indicator to regulate precise indices for the open space settings. In this study, the authors described different indices and related feeling type. Then, the authors matched the consequences of the survey and the thermal perception group of the indices. The outcomes of the assessment determine that physiological equivalent temperature is a precise index for assessing the thermal environment [51]. Behzadfar and Monam (2012) by assessment of the diverse SVF in urban-parks in Tehran/Iran through the Ta, Tg and Tmrt, presented that SVF is more linked to the Mean Radiant Temperature than the Ta and Tg in the park. Following this study, the properties of different thermal parameters on each other and not on the basis of different indices have been evaluated. Therefore, the effect of shaded open spaces on the campus is to show the effects of the PET on the heat sensation [52].

2. METHODOLOGY

2.1. Study area

This research was directed in Tehran/Iran (51° 20' E, 35° 41' N, and altitude =1368m), with a population of eight million and with a moderate-climate and warm summers. Most significant Iranian universities are positioned in Tehran and hundreds of pupils come to Tehran to study. IUST is placed in the eastern part of Tehran with an area of 420000 m^2. Most of the campus is sheltered with green spaces, and because of its outdoor areas, Ta in the campus has been enhanced the condition rather than the surrounding urban context. AUT is one of the best universities in Tehran, but the campus is not as small as the outdoors, so it can be paralleled with IUST at a point in terms of outdoor comfort conditions and its related factors SVF, PET and PET. Using weather data from 20 years of air temperature measurements in the capital city of Iran, This may conclude that from January 15 to March 1, the city's weather is very cold, but it is cold from March to mid-April and also from mid-December to January 15. From April 15 to 15 days, the weather is a bit cold. Before December, for about 45 days, it is a bit cold. People like the settings in May and June and wish to stay at this Ta. This is also true in October. The first 15 days of July feel warm days and the second 15 days and feel warm Ta. But the days are very warm in August and based on this category, the weather is warm in the first 15 days of September [53].

2.2. Materials

In this paper, 20 locations of these campuses (educational zones) were designated to be measured in terms of thermal conditional of the Ta in Tehran.

Weather data (Ta, Ws, and RH) were recorded in 15^{th} of each month (March 21 until September 22 of 2015). The measurements of the meteorological data were done via Data logger, type: Lutron LM-8000 (A Lutron LM 8000 4 in 1 digital anemometer, hygrometer, light meter and thermometer for measuring wind velocity, humidity, light intensity, and temperature).

TLutron LM-8000 (Data logger) was applied automatically to set the Ta and wind speed and RH at intervals of 60 min automatically between 10:00 and 18:00 for the spring and summer 2015 seasons. As the next step, the data was calculated on average by Excel software.

Fig. 1 Metrological data logger (Lutron LM-8000)

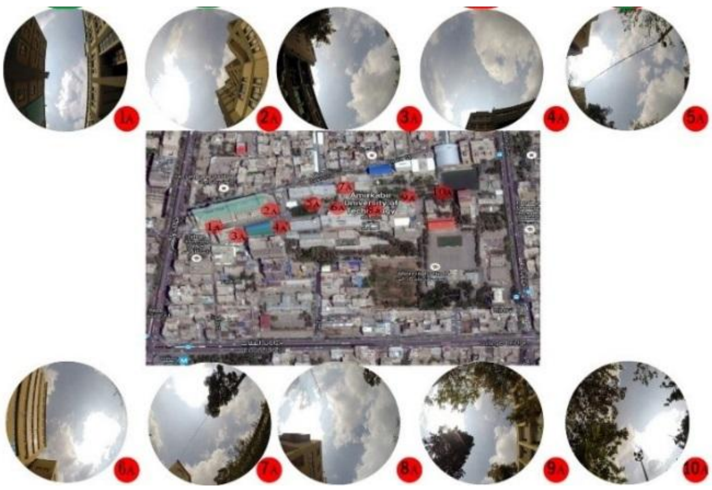


Fig. 2 The study location: AUT from wikimapia (http://wikimapia.org) representing the SVF values

Fig. 3 The study location: IUST from google map (http://maps.google.com/) representing the SVF values

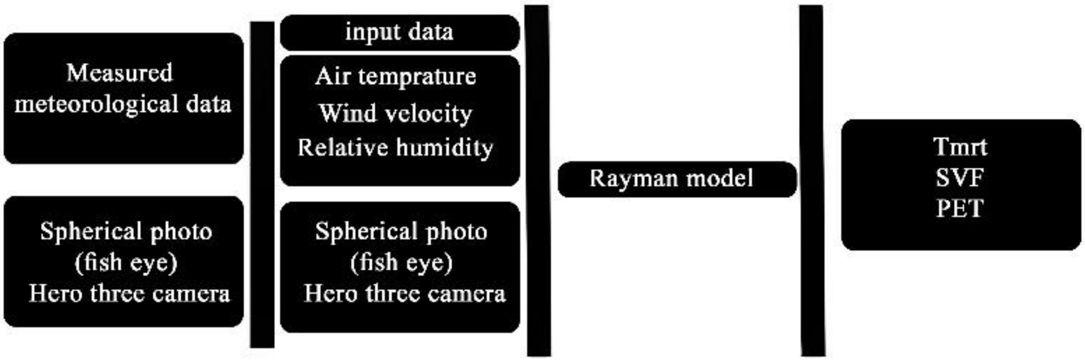


Fig. 4 Procedure of the study

Fisheye picture for determining the SVF has been chosen using a Hero-3 (fisheye lens) tool. These pictures have been examined based on atmosphere surface and hue algorithm. 10 locations in the site (educational site) of AUT have been designated. Assortment of this location was based on the Sky View Factor and the purpose was to have a widespread value of SVF. The pictures were captured on August 20 at 1-2 p.m. Location 1A (space among Faculty of Electrical and Mechanical and Oil engineering) with 0.437 has the lowermost SVF and 4A (front area of exhibitions) with 0.918 has the highest SVF and the average SVF on this campus is 0.7206.

Through the AUT, 10 locations were designated from the campus of IUST (educational zones). The purpose was to have a varied value of this parameter. These fisheye pictures were captured on August 20 at 11-12 a.m. Point 4E (Space of restaurant and self-service) with 0.161 as the lowemost Sky View Factor and 1E (faculty of physics) with 0.633 has the highest SVF value and the mean value of Sky View Factor on this campus is 0.3305**.**

The Rayman model was used to compute the PET according to the SVF of the campuses [54]. The thermal comfort of open space of these campuses (educational zone) will be argued and matched further. The effect of MRT according to SVF is resulting from the Rayman software. Fig.3 shows the process of study in the long-term. The SPSS software and Excel were used to compare and discuss on the PET, Tmrt, and SVF**.**

2.3. Calculation of PET as thermal comfort index

The physiological equivalent temperature, PET, is a thermal index derived from the human energy balance. It is well suited to the evaluation of the thermal component of different climates as well as having a detailed physiological basis [55].

The PET index is often used in environmental comfort research for analyzing the physiological behavior of users and pedestrians according to environmental conditions (effect of buildings and climate) [56]. PET as thermal comfort has been used in several studies of outdoor thermal comfort [57-61]. Because the PET index has been primarily designed for outdoor use [62], PET can be calculated using free software (Rayman). This software is validated software for urban complex shading [63-64]. Environmental data for the PET calculation that is required in the Rayman model includes air temperature (T_a), relative humidity (RH%), wind velocity (v), mean radiant temperature (Tmrt) and vapor pressure (VP) and personal data such as human clothing and activity and local data such as date of year, time and location. Using this process, assessment of PET can be calculated by importing spherical photos (fisheye pictures) of the sky to calculate the short and long wave radiation fluxes. After importing these parameters to the Rayman model, the Tmrt, SVF, PET and other thermal indices represent the software output.

2.4. Sky view factor (SVF)

The analysis of the SVF in both campuses has been done by the authors [61] and it is necessary to be described again here to give scientific awareness of the built environment of the campuses. Therefore, the data ahead are reported here as a part of the area study.

2.4.1. SVF of AUT

The charge of SVF is in the range of 0.437<SVF<0.918 and 70% of the designated locations have a Sky View Factor in excess of 0.7 and based on the mean value of SVF 0.7206, 72% of surfaces on this campus getting straight solar radiation.

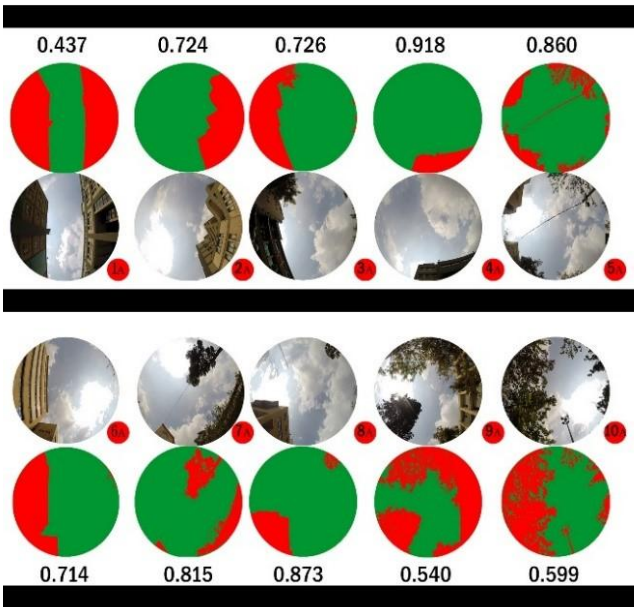


Fig. 5 Fisheye picture of AUT campus

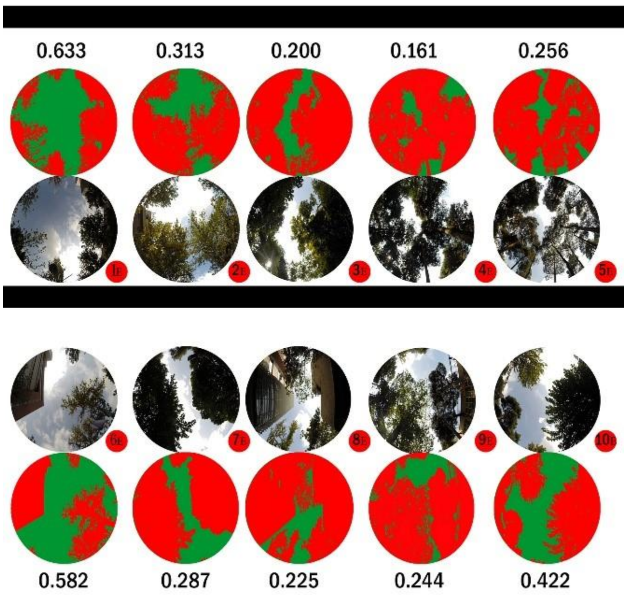


Fig. 6 Fisheye picture of the campus of IUST

2.4.2. SVF value in the campus of IUST

The variety value of SVF is 0.161<SVF<0.633 and 60% of the designated location have a Sky View Factor of in excess of 0.3 and based on the mean value of SVFs (0.3305), 33% of surfaces on this campus getting straight sun radiation and 67% of the educational region of the IUST are in the shaded situation.

2.4.3. Comparison

Concerning the dissimilar amount of shadows of these two campuses, there were 2 diverse values of Sky View Factor level that were stated. The mean value of Sky View Factor at AUT is 0.7206 and in IUST 0.3305. Dissimilar SVF value of these 2 campuses makes diverse shaded place forms. Accordingly, the pupils have diverse chances to adjust their thermal activities with their surrounding places.

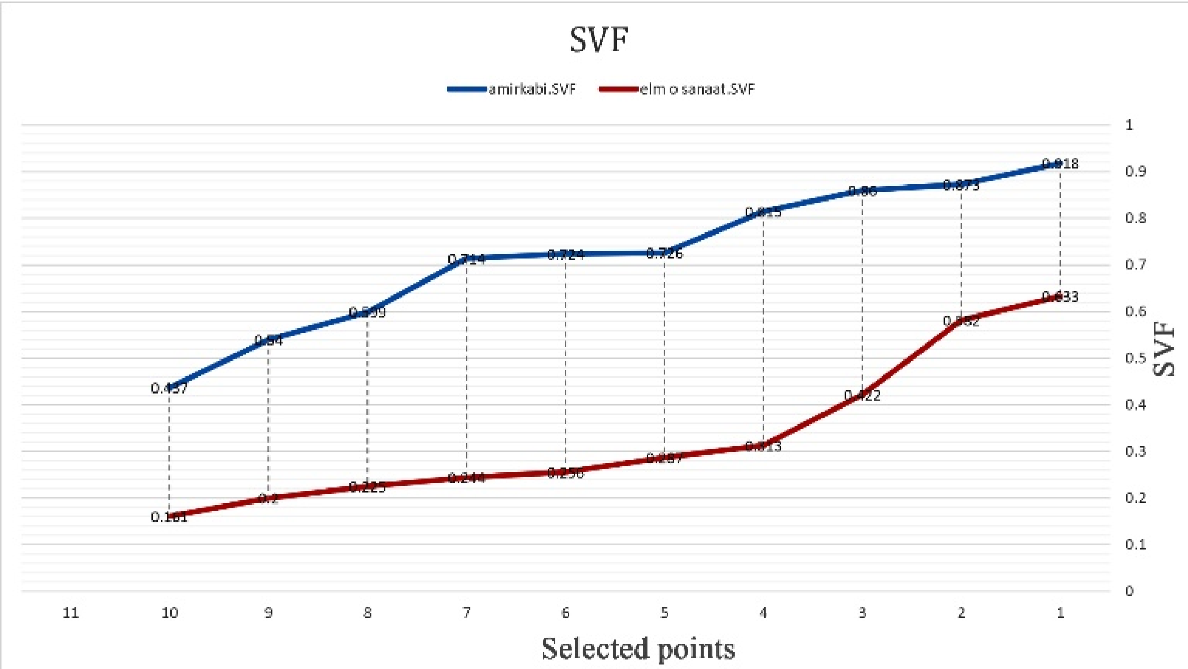


Fig. 7 Comparison of Sky View Factor values of two campuses

According to the previous investigation which has been done for AUT, the relationship table of Sky View Factor and Mean Radiant Temperature of IUST demonstrated that through the year but in April, the Pearson correlation is higher than 70%. By matching these 2 open spaces, it can be assumed that there an adequate relationship among Sky View Factor and Mean Radiant Temperature to consider for creating more shadows space to decrease of Mean Radiant Temperature in landscape and urban designing principles to gain a more sustainable environment.

3. RESULTS AND DISCUSSION

3.1. AUT

3.3.1. Physiological equivalent temperature (PET) of the campus of AUT

According to the PET comfort classification, comfort conditions on the campus of AUT occur in May and September whereas April experiences cool conditions, June experiences hot conditions, and July experiences very hot thermal conditions.

Numerical analyses of the 60 points (10 points over 6 months), highlight that just 10 points of 60 are in the comfort condition (all of them are in May and September) and the other (50 out of 60) points are in the discomfort condition.

3.3.2. SVF-PET

Numerical analyses of SVF and its related PET as shown by the following chart highlights that the lowest temperature of each month is linked to the lowermost Sky View Factor and also the uppermost temperature in the PET scale is related to the highest SVF. The maximum difference in the subtraction of the highest and the lowest temperature is in June, of 4.5°C and the minimum difference is in April.

In terms of SVF value on the campus of AUT, 7 of 10 designated location have a Sky View value higher than 0.7, which means that there is less opportunity to adapt thermal behavior with shadows to mitigate thermal stress.

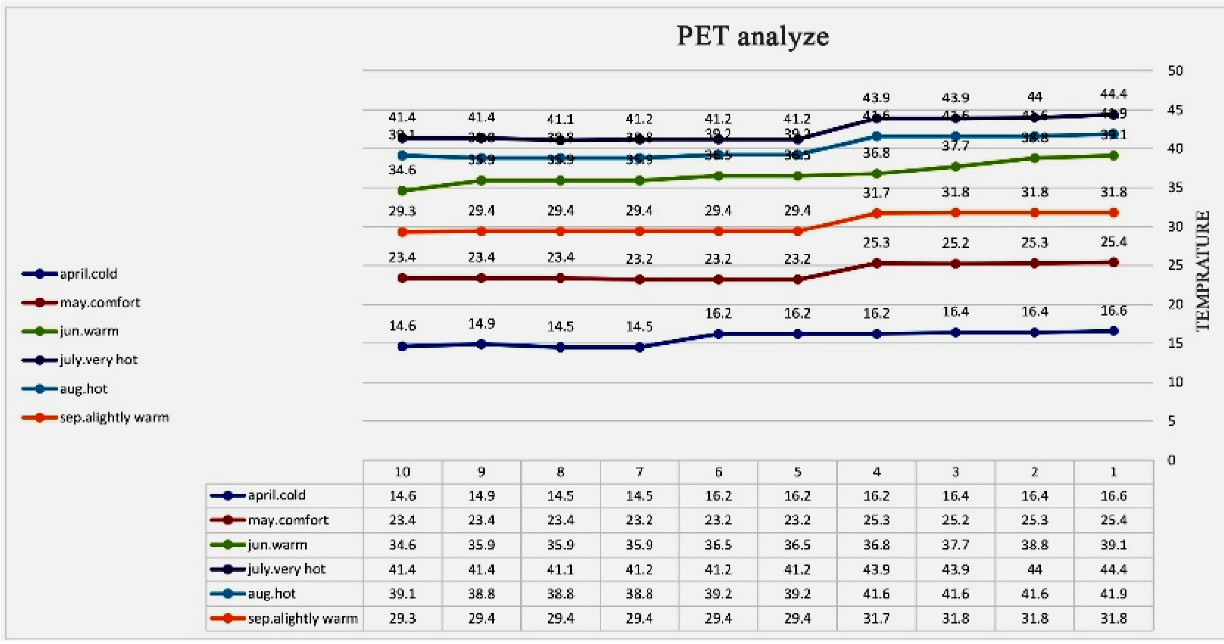


Fig. 8 Monthly drawing of PET according to the related SVF value

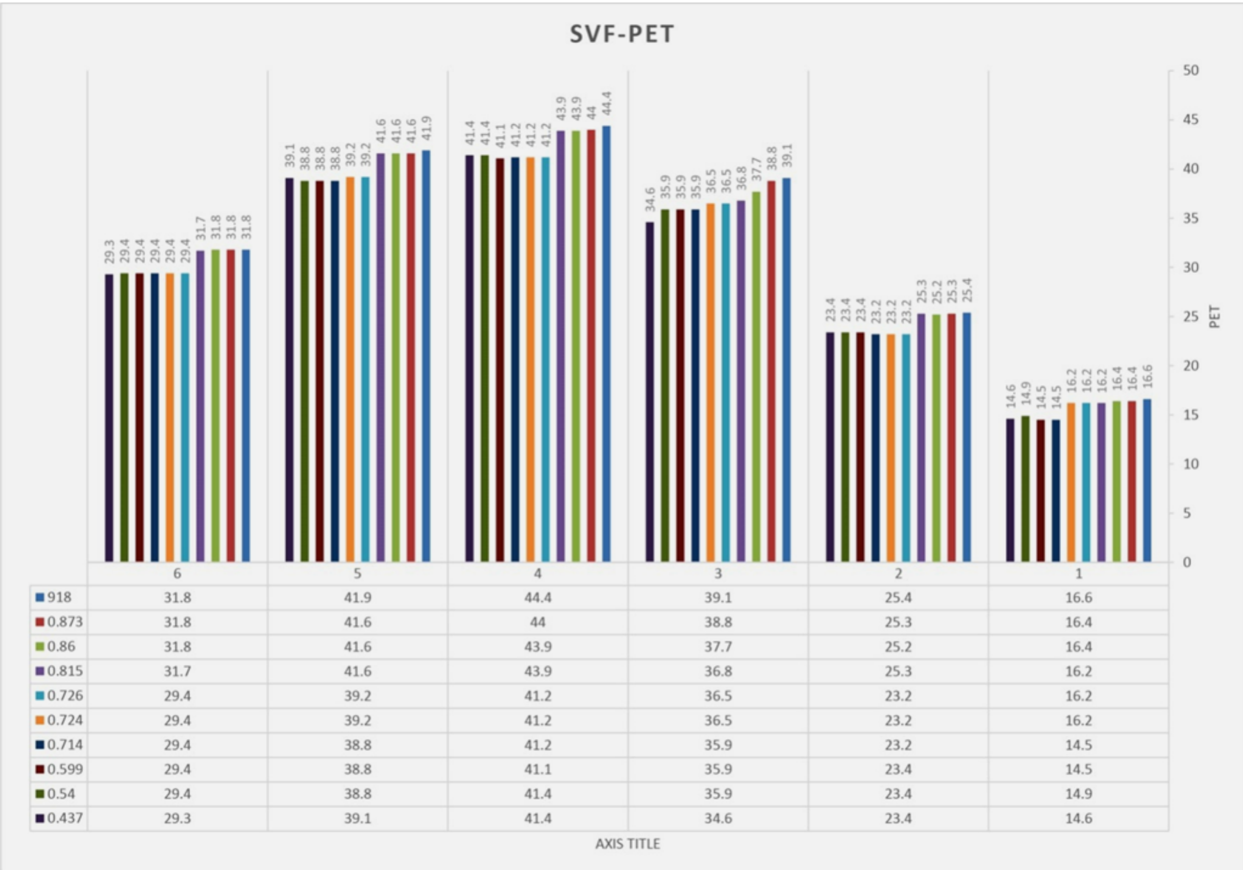
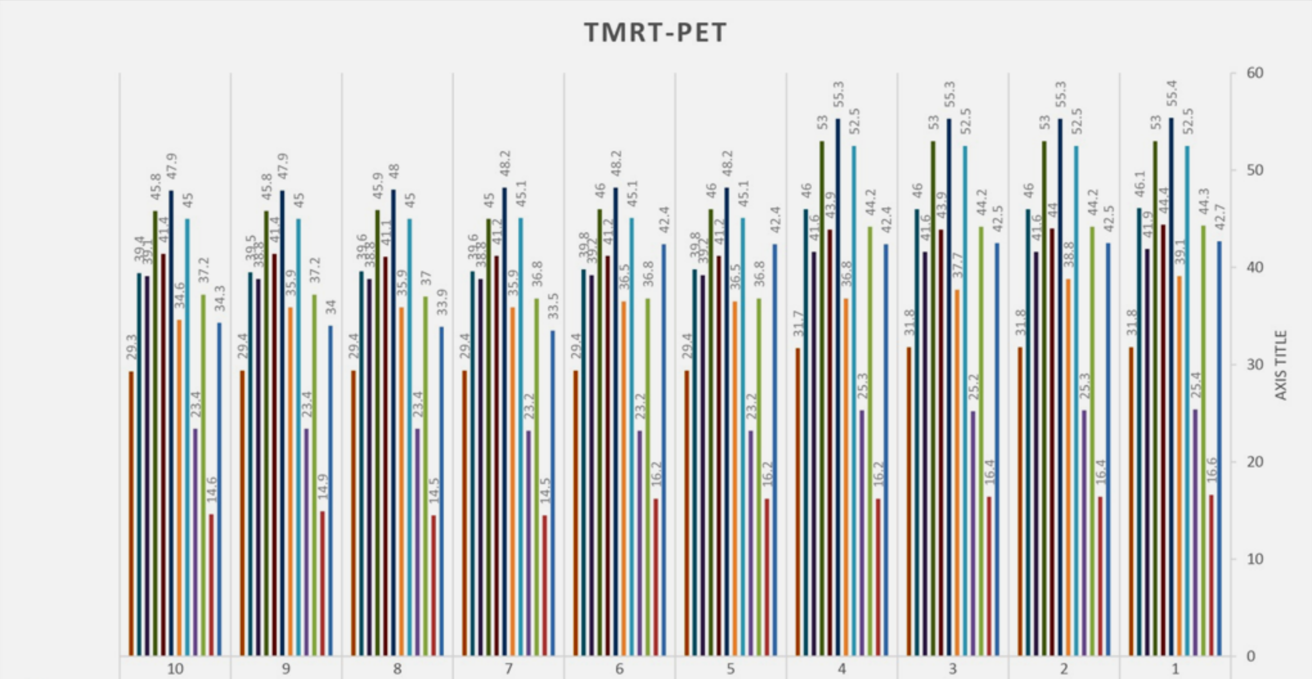


Fig. 9 Analyses of PET according to matched SVF

3.3.3. Tmrt_PET

As mentioned above, Tmrt as heat stress indicator and its correlation with SVF have been mentioned before (observed in both campuses). The measured PET has been analyzed numerically. The analysis shows that in all 6 months and across all 60 points, the uppermost Mean Radiant Temperature is related to the highest PET. In the following chart, each PET is represented by its Tmrt. In each category that is based on SVF (10-points category), there are 6 PETs that are related to the 6 months and 6 Tmrt are related to the 6 months and it shows that the highest Tmrt and PET is linked to the uppermost Sky View Factor and by decreasing the SVF value, the Tmrt, and PET also decrease. According to the following chart, all the points that have the highest SVF value also have the highest Tmrt and in the same way, the same point reaches the highest PET.



	10	9	8	7	6	5	4	3	2	1
tmrt.april	34.3	34	33.9	33.5	42.4	42.4	42.4	42.5	42.5	42.7
pet.april	14.6	14.9	14.5	14.5	16.2	16.2	16.2	16.4	16.4	16.6
tmrt.may	37.2	37.2	37	36.8	36.8	36.8	44.2	44.2	44.2	44.3
pet.may	23.4	23.4	23.4	23.2	23.2	23.2	25.3	25.2	25.3	25.4
tmrt.jun	45	45	45	45.1	45.1	45.1	52.5	52.5	52.5	52.5
pet.jun	34.6	35.9	35.9	35.9	36.5	36.5	36.8	37.7	38.8	39.1
tmrt.july	47.9	47.9	48	48.2	48.2	48.2	55.3	55.3	55.3	55.4
pet.july	41.4	41.4	41.1	41.2	41.2	41.2	43.9	43.9	44	44.4
tmrt.aug	45.8	45.8	45.9	45	46	46	53	53	53	53
pet.aug	39.1	38.8	38.8	38.8	39.2	39.2	41.6	41.6	41.6	41.9
tmrt.sep	39.4	39.5	39.6	39.6	39.8	39.8	46	46	46	46.1
pet.sep	29.3	29.4	29.4	29.4	29.4	29.4	31.7	31.8	31.8	31.8

Fig. 10 Analyses of PET with their matched MRT for through year according to SVF

3.4. IUST

3.4.1. Physiological Equivalent Temperature (PET) of the campus of IUST

Monthly evaluations of the PET in the campus of IUST are shown according to the PET classification. It highlights that May and September experience comfort conditions and April experiences cool conditions and June's thermal condition is warm. July and August are hot (the thermal conditions of July on the campus of AUT was very hot).

All 60 points were analyzed statistically and the result shows that 11 points out of 60 are in the comfort condition and the other 49 points are in the discomfort condition and also 11 points out of 60 have more than 40°C in the PET scale (compared to 17 points in AUT). This means that shaded places are more prone to have more of a comfort condition.

Fig. 11 Monthly diagram of PET according to correlated SVF variations

3.4.2. SVF-PET

The campus of IUST (faculty zones) because of a high shaded open spaces, has a lower SVF value, and numerical analyses of PET based on SVF (10 points) over 6 months highlight that the thermal conditions of this campus are more fixed and PET changes in terms of SVF are very low and the maximum PET is linked to the Sky View Factor value of 0.633. The PET has rapid changes at this point and before this (in the other 9 points) the PET changes happen gradually. Because of the low SVF value, ground surfaces of this campus have more shadow, and high shaded surfaces make the environment more adapted in terms of thermal behavioral adaption.

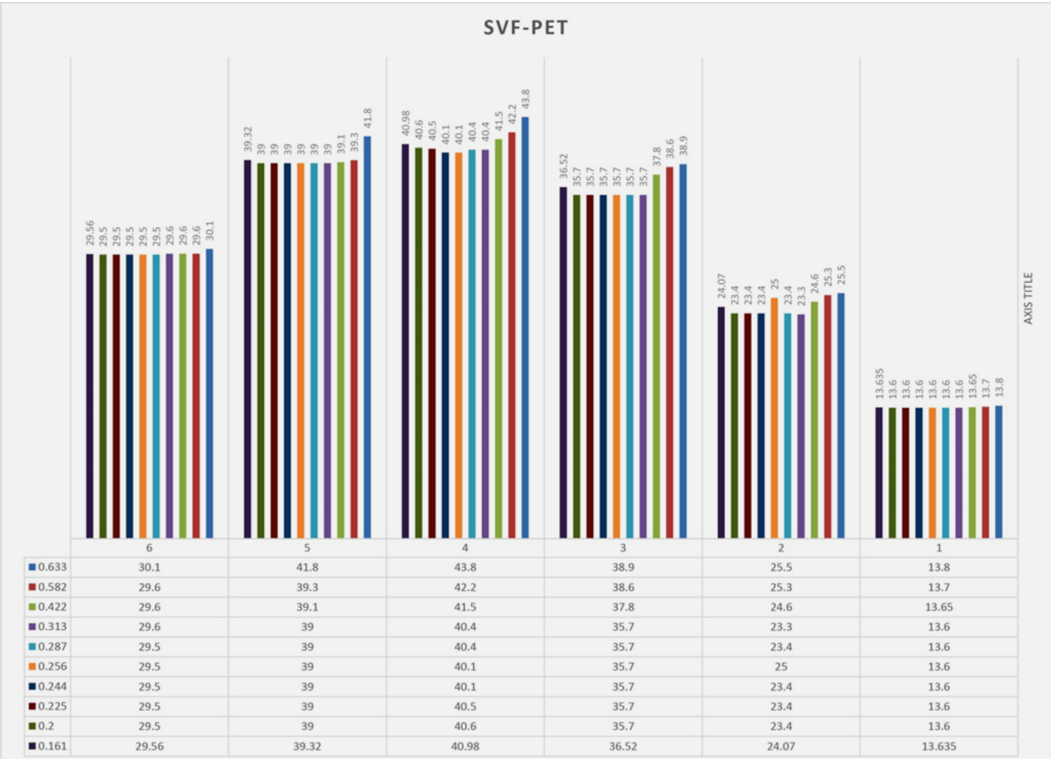
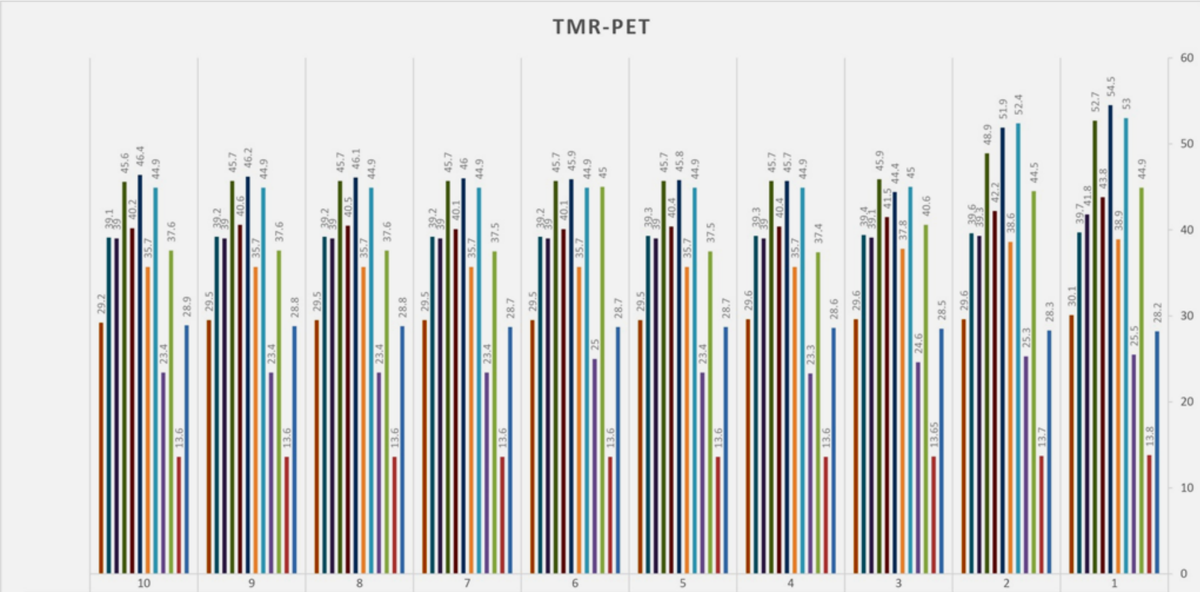


Fig. 12 Investigation of PET based on the related SVF value

3.4.3. Tmrt –PET

Tmrt and its related PET, have been analyzed numerically. The results show that in all 6 months and across all 60 points, the uppermost MRT is connected to the uppermost PET. In the following chart, each PET is represented by its Tmrt. In each category that is based on SVF (10 categories), there are 6 PETs that are related to the 6 months and 6 Tmrt values are related to the 6 months and it shows that the highest Tmrt and PET are related to the highest SVF and by decreasing the SVF value, the Tmrt and PET decrease too. The point that has the lowest SVF value reaches the lowest Tmrt and in the same way, the same point reaches the lowest PET.



	10	9	8	7	6	5	4	3	2	1
april.mrt	28.9	28.8	28.8	28.7	28.7	28.7	28.6	28.5	28.3	28.2
april.pet	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.65	13.7	13.8
mrt.may	37.6	37.6	37.6	37.5	45	37.5	37.4	40.6	44.5	44.9
pet.may	23.4	23.4	23.4	23.4	25	23.4	23.3	24.6	25.3	25.5
mrt.jun	44.9	44.9	44.9	44.9	44.9	44.9	44.9	45	52.4	53
pet.jun	35.7	35.7	35.7	35.7	35.7	35.7	35.7	37.8	38.6	38.9
mrt.july	46.4	46.2	46.1	46	45.9	45.8	45.7	44.4	51.9	54.5
pet.july	40.2	40.6	40.5	40.1	40.1	40.4	40.4	41.5	42.2	43.8
mrt.agu	45.6	45.7	45.7	45.7	45.7	45.7	45.7	45.9	48.9	52.7
pet.agu	39	39	39	39	39	39	39	39.1	39.3	41.8
mrt,sep	39.1	39.2	39.2	39.2	39.2	39.3	39.3	39.4	39.6	39.7
pet.sep	29.2	29.5	29.5	29.5	29.5	29.5	29.6	29.6	29.6	30.1

Fig. 13 Analyses of PET with their correlated MRT through year according to SVF

3.5. Comparison of PET thermal index based on Tmrt and SVF

The average of the PET index has been evaluated for each month and compared in one graphical diagram. According to the chart, the campus of IUST is 0.86°C cooler than the campus of AUT and in July there is 1.39°C difference in PET values. In this diagram, we analyzed the mean radiant temperature again, to demonstrate how changes in T_{mrt} can affect the PET. According to the diagram, maximum differences between Tmrt of campuses is in July (6 evaluated months) so as the similarly the maximum difference between PET of campuses is in July. We have evaluated Tmrt by the Rayman model. According to the previous sections (correlation of Tmrt and SVF), on the campus of AUT with high SVF values, the correlation of Tmrt and SVF highlights that in the environment with high sky-view conditions, the thermal comfort condition is strongly affected by the Tmrt.

In the succeeding drawing, the correlation of the MRT and Physiological Equivalent Temperature have been defined by a regression coefficient drawing. In AUT, the R^2 value is 0.9133 and in IUST University, it is 0.945.

All of these values (R^2) illustrate the high relationship among MRT and Physiological Equivalent Temperature which toughly touch thermal comfort. The modifications of MRT in these campuses consequence from the Sky View Factor variances and the Sky View Factor amounts of two campuses is matched with the greenery.

Furthermore, MRT drop by decreasing the Sky View Factor value would improve the user's adaptation by cumulative the shadow would create the campuses more adaptive students.

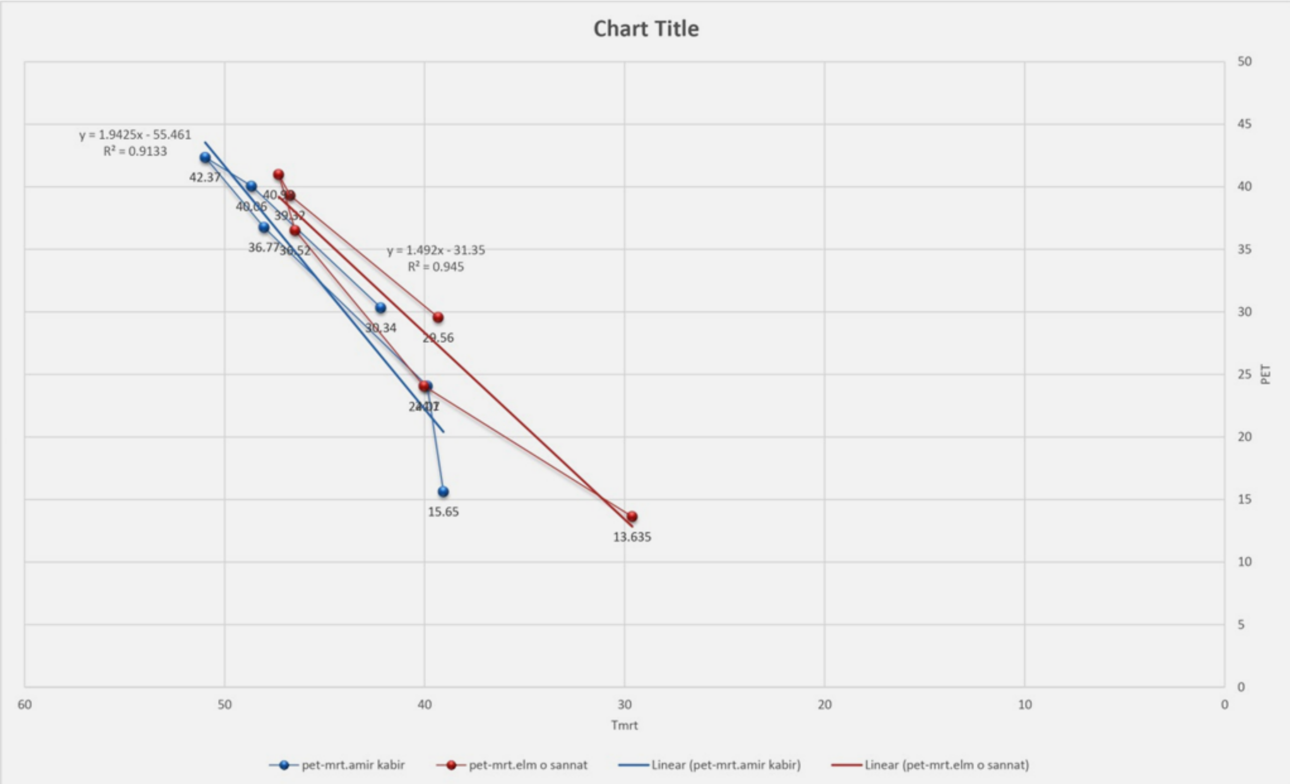


Fig. 14 Comparison of correlation PET of both campuses

4. CONCLUSION

Thermal comfort in the open spaces is a significant parameter in public mentally and physically healthy. Increased hot days of cities because of the urban heat island is the common phenomenon in cities. This phenomenon effect cites quality by a different aspect such as air quality, use of fossil fuels, etc. Therefore, cooling strategies in the urban and similar spaces like campuses design is one of the important issues of the designers. This research emphases on two campuses' outdoor thermal comfort. The thermal comfort of these two campuses was investigated by the Rayman software to calculate the PET index. This research efforts to demonstrate the influence of different shadow forms, particularly in the campus, to raise the thermal comfort of students. The consequence of research is to create outdoor setting for relative coatings for the thermal condition. The writers inspected 10 locations on both campuses (educational area). Amount of climatological data for half of the year of 2015. In this research, MRT was examined by altering the values of Sky View Factor and the related influence on Physiological Equivalent Temperature. Sheltering effects of greenery in campuses decrease the mean value of the MRT (3 68 ° C in July, in 6 months, 17 / 3.22 ° C MRT). The Physiological Equivalent Temperature index was examined according to MRT. The findings demonstrate that the campus is 86/86 degrees is cooler than the AUT campus in Physiological Equivalent Temperature Scale in July. There is 1.39°C difference in the evaluation of PET. In conclusion, increasing shaded spaces by increasing green spaces and trees can create cooler campuses and more to point, integrated design of architectural forms and green spaces decreases the high sky exposed open spaces and by this means, heat stress mitigation is an outcome of the low radiated open spaces. Consequently, cooler campuses are more prone to be used by students and their different activities. This investigation is looking for a cool location in a thermal environment with an accurate index for open spaces. Tmrt's relationship with Physiological Equivalent Temperature will allow architects to anticipate and solve environmentally climatic problems and create comfortable spaces.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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