

## Pedestrianization of a Vehicular Urban Corridor: Designing for User Comfort

Andreas L. Savvides<sup>1</sup>

### Abstract

This paper examines the spatial and bioclimatic considerations that are embedded in the formulation of open spaces for collective use in a major thoroughfare, Makariou, in the capital region of the island-country of Cyprus, in the Eastern Mediterranean. The climatic context of Cyprus is indicative of the broader geographical region of Southeastern Europe, the Middle East and North Africa. For purposes of comparative analysis, existing and proposed redevelopment conditions are juxtaposed, to visualize and quantify conditions of thermal and visual user comfort by varying the materials palette and landscape accessorization of the site in question. The results are based on an environmental simulation using Ecotect by Autodesk and a discussion of the findings aims at examining inherent conditions that account for user comfort in such locales, as well as evaluating aspects of sustainable design in existing open spaces and the potential to transfer lessons learned in contemporary design practices.

**Keywords:** Vehicular corridor, pedestrianization, bioclimatic design, user comfort.

### 1. Introduction and Points of Reference

In the design of functional and evocative collective spaces in the contemporary city, it is important to revisit the lessons of the past and to consider the complexity of issues involved in user thermal comfort in outdoor urban spaces. The initial findings of the research being presented here seek to achieve a better understanding of the richness of microclimatic characteristics in outdoor urban spaces and the comfort implications for the people using them. These conditions influence people's behaviour and usage of outdoor spaces. In evaluating responses to their research questionnaire, Nikolopoulou, Baker and Steemers (Nikolopoulou et al., 2001) note that awareness of the microclimate may be unconscious, but awareness may often result in a different use of urban space in different climatic conditions.

Improved microclimatic conditions have in turn major implications for the development of cities. By controlling sources of discomfort, sedentary activities, as well as the use of public transport, cycling and walking, are promoted, which are the goals of the public authorities engaged in envisioning alternative futures for the Makariou thoroughfare under study. Successful areas attract large numbers of people, which in turn attract businesses, workers, residents and the area becomes economically profitable. Moreover, successful outdoor spaces may benefit the image of the city.

There is also adequate understanding of the influence of climate on urban settlements. For example, according to Nikolopoulou, Baker and Steemers (Nikolopoulou et al., 2001), the way self-shading streets protect the buildings and the surrounding spaces from the hot sun, in hot arid climates or dispersed buildings and vegetation that allow for easy flow of wind through the spaces in hot humid climates, help create an appropriate architectural vocabulary by adapting it to the peculiarities of the local climate. In cases where the urban fabric is existent, such as the case of Makariou, alterations are possible down to the scale of the urban block to exert microclimatic control. Shading whole streets is feasible whether in the form of trees, with the advantage of cooling via evapotranspiration through the leaves or man-made canopies with the available materials and appropriate, topical solutions.

<sup>1</sup> University of Cyprus, P. O. Box 1678, Nicosia, Cyprus. Email [als@ucy.ac.cy](mailto:als@ucy.ac.cy) | Tel. +357-22-892967 | Fax. +357-22-895056

Furthermore, a quantitative approach to the physical parameters has demonstrated that microclimatic parameters, indeed, strongly influence thermal sensations and these form the main focus of this investigation. However, the work of Nikolopoulou and Steemers (Nikolopoulou and Steemers, 2003) has thrown some light on the fact that psychological adaptation seems to become increasingly important as well. Although it was demonstrated that psychological adaptation is very important for the thermal evaluation of outdoor spaces and there is strong influence between the different parameters, it has been difficult to develop these speculations in more depth or to indicate more deterministic relationships to date and this body of work will not venture to develop that prong of investigation.

It is important to note, however, that appropriate microclimatic planning and careful design of urban spaces can provide protection from negative aspects and exposure to positive aspects of the climate, therefore, increasing the use of outdoor space throughout the year. Different seasons require different approaches, but a variety of spaces providing different environments would maximize both physical and psychological comfort. The physical environment and psychological adaptation has been argued by Nikolopoulou and Steemers (Nikolopoulou and Steemers, 2003) to be complementary rather than contradictory and consideration of this duality could increase the use of a city's open spaces, strengthening social interaction between users by allowing opportunities for such interaction to take place.

Picot also shows that vegetation should be considered as a real tool for the control of microclimatic conditions in external spaces (Picot, 2004). In the present case study, this becomes a reality when trees reach their adult dimensions and are considered in alternative layouts along the Makariou thoroughfare. The screening potential of the tree foliage with the direct effect of reducing the solar radiation absorbed by a typical person situated below a tree canopy is considerable. Trees absorb and reflect the biggest part of the solar radiation and the data obtained shows that vegetation should be seen as an active element, reflecting energy that can increase the terrestrial radiation absorbed by a person. The use of vegetation as a tool in microclimatic control therefore needs to take into account the shading performance evolution of vegetation and eventually provide temporary and complementary screening solutions. These can be included in projects in various ways, such as, urban furniture, seasonal fabric screens and / or artificial canopies with the aim of providing shade. These parameters need to be further studied even if empirical experiences show that various greening initiatives located in a neighborhood of the buildings can modify the relationship with their environment and the sensations of the users.

Although not verified in this study patterns discussed before by Ali-Toudert and Mayer (Ali-Toudert and Mayer, 2006) give some information about the most suitable locations of trees within the street to improve its comfort level and this has been taken into account in the simulations in this body of work. In all cases, tree plantings in streets of about  $H/W \approx 0.5$  ratios have been shown to be suitable, while for higher aspect ratios, the overheated E-W streets are likely the ones where the implementation of vegetation is most desirable because the discomfort duration is long. Trees would preferably be located on the south-facing side or in the central part of the street, depending on the aspect ratio and street use.

Another consideration by Ali-Toudert and Mayer (Ali-Toudert and Mayer, 2006) is the use of materials with high thermal capacities, which would help reduce the long-wave radiation fluxes from the surrounding surfaces in the daytime and consequently decrease perceived higher temperatures.

Regarding the wind, there is increasing discomfort as wind speed increases, depending on air temperature, as at high air temperatures the cooling effect of the wind is desired. According to Nikolopoulou and Lykoudis and in relation to user comfort (Nikolopoulou and Lykoudis, 2006), the majority of the people found outside have reported feeling comfortable, exceeding 75% for all cities on a yearly basis. Sources of discomfort include strong wind at northern climates and stale conditions for air temperatures over 30 degrees Centigrade. Regarding humidity, people are not very good at judging changes in humidity levels, unless relative humidity is very high or very low and normally in conjunction with temperature conditions, indicating a significant second role for relative humidity in the overall comfort sensation.

Again according to Nikolopoulou and Lykoudis (Nikolopoulou and Lykoudis, 2006), investigating the temperatures where people feel neither warm nor cool, showed a great variation across Europe of over 10 degrees

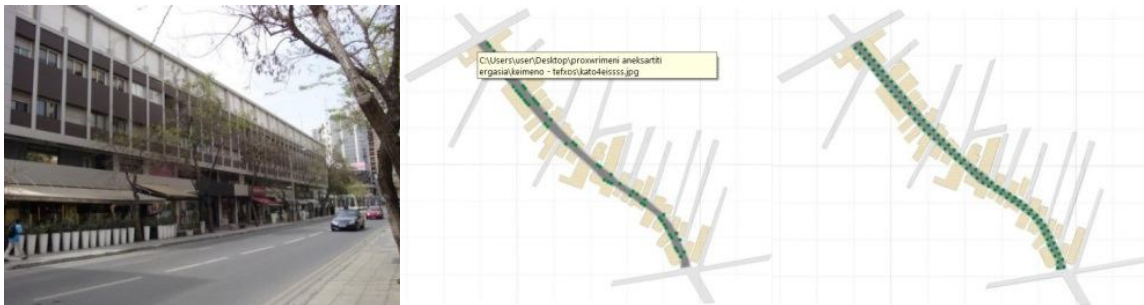
Centigrade, just below, 23 degrees Centigrade for Athens, in Greece (which forms an approximate datum for the current analysis) and 13 degrees Centigrade for Fribourg, in Germany.

Transitional seasons have wider neutrality zones for southern cities, such as Nicosia, yet this difference is minimized for northern cities in Germany, for example. For the purposes of this study this could be attributed to the difference in behavior between the southern and the northern cities, a result of experience to a different range of climatic conditions and difference in sensitivity to heat and cold.

## 2. Methodology of investigation

As mentioned in the introduction above, both paving material choices as well as tree planting of outdoor open spaces and circulation corridors affect an area's microclimate especially as their surface temperatures increase or decrease the perceived temperature of a space as a result of direct or indirect insolation. The study presented focuses on an evaluation of the environmental design qualities of plans to reconfigure the spatial characteristics of Makariou, a major thoroughfare in Nicosia, as outlined by Oratiou (Oratiou, 2013) and with respect to choices to be made for new paving materials and tree plantings as compared to the current situation.

Simulations of existing and proposed conditions are carried out using the software Ecotect by Autodesk to compare the results prevalent user comfort conditions as they pertain to perceived temperatures at various datum elevations above street level, the extent of shading as a result of tree plantings and the lighting levels at regular points along the corridor under investigation. The study also includes comparisons of the above mentioned parameters based on the utilization of different paving material choices and different configurations of tree planting along the corridor. The typical condition of the existing state of the thoroughfare, as well as the proposed reconfiguration of access lanes for the various mobility choices planned for the future, are shown below, Figures 1, 2 & 3 shown below.

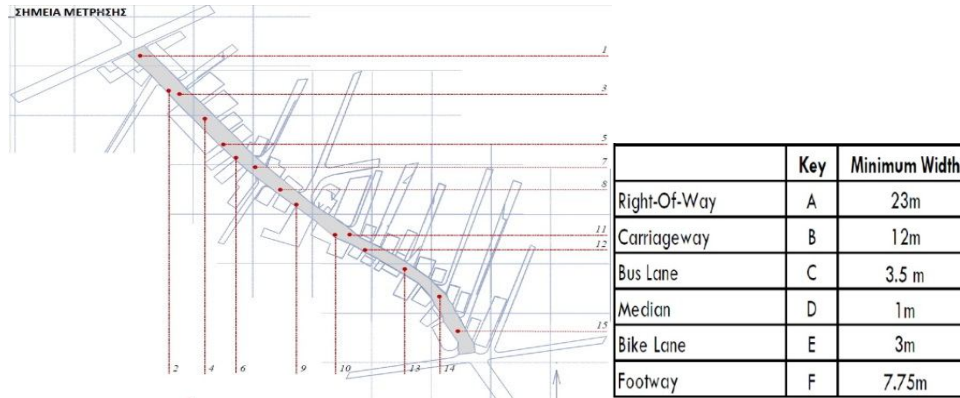


**Figures 1, 2, 3:** From left to right: Current state of Makariou thoroughfare; existing conditions plan; proposed redevelopment plan.

The modelling of the street followed taking into account the materials of construction for the various buildings adjacent to the Makariou thoroughfare, which included the material treatment of building facades in the vertical plane and the material treatment of the horizontal surfaces of the thoroughfare. In addition to the prevalent materials of construction which characterized the building facades and which consisted primarily of exposed concrete, painted concrete, metal panels and infill glazing, the horizontal paving materials included asphalt in conjunction with limestone, pavers, concrete pavers, granite blocks, concrete blocks and local brick pavers.

The environmental simulation and analysis used climatological data from the nearby Larnaca District in Cyprus (in the Eastern Mediterranean, approximately 33.5 degrees east, 35 degrees north) for three different times of the year, namely December 21st, March 21st and June 21st with clear skies. The simulations were organized around fifteen data points, Figures 4 & 5 shown below, they were scheduled for three periods during the day, at 08:00, 12:00 and 16:00 hours and the recorded temperatures were planned at ground level and subsequently at levels 0.60m, 1.20m, 1.80m and 2.40m above ground. Lighting levels and the way these were affected by existing building massing as well as by tree planting and by paving material choices were calculated in (lux) for the times of year and times of day mentioned above. Spatial analysis of lighting levels was also taken from four key nodal points along the Makariou thoroughfare. For the purposes of simulating used comfort under these conditions, certain user based parameters

were accepted, such as the software zones related to: clothing level (taken as 'light business suit'), air speed (low) and humidity (at 60%), with no other factors affecting the simulation parameters.



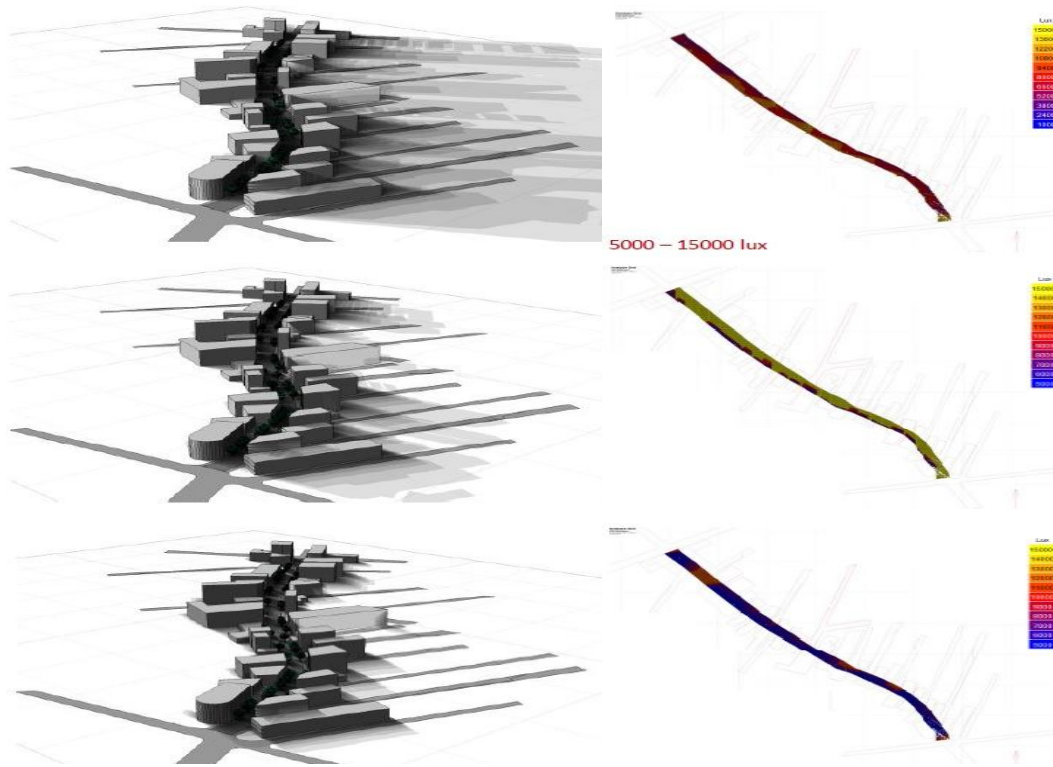
**Figures 4 & 5:** Data collection points, spaced at key locations along Makariou thoroughfare; Dimensions of reconfigured thoroughfare.

### 3. Simulation and Discussion of the Results

The recordings of the data extracted from the various scenarios of the simulation as outlined above were tabulated and compared. The recordings took place at fifteen locations along the Makariou thoroughfare and considered for five different tree planting scenarios, which were in turn submitted to three sets of paving material treatments as outlined above. Indicative observations and comparisons of the results collected are presented below for the various indicators considered, juxtaposing the existing conditions and the preferred future development scenario, based on the variations of the parameters outlined above.

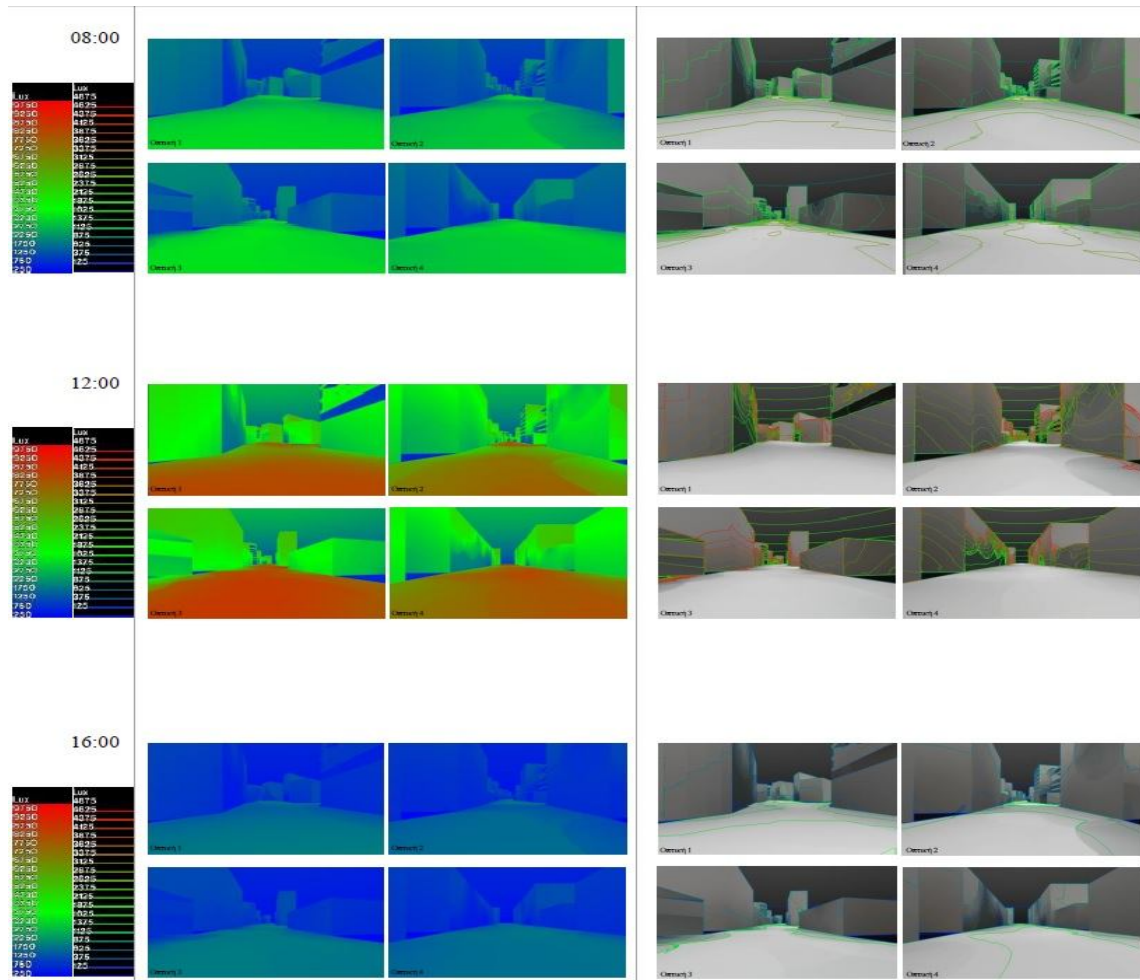
#### 3.1 Lighting Levels

The mediation of solar insolation and the provision of shaded areas in the site investigated constitute some of the most important factors that regulate microclimatic conditions in urban spaces, Figures 6 & 7 shown below.



**Figures 6 & 7:** Simulation of building massing along Makariou thoroughfare and indicative lighting levels study at three different time slots.

In the simulation exercise, the lighting levels for the existing conditions as compared to those of the future development scenario show marked differences. The data recorded for the existing conditions, Figure 8 shown below, indicate a level of 15000+ (lux) for 93% of the site on June 21st at 12:00 as compared the future development scenario with the same parameters, which ensures only 80% (a 13% reduction) for 15000+ (lux). Also, data for December 21st for all three time periods and on March 21st for the 08:00 slot are down to 20% of the site with values of 7000 (lux) and 12000 (lux) respectively for the proposed scenario as compared to 40% of the site at 15000+ (lux).

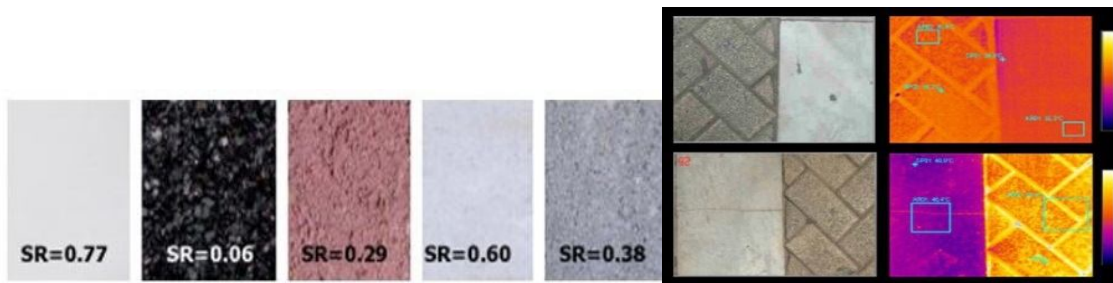


**Figure 8: Lighting levels at key locations along Makariou thoroughfare.**

The proposed scenario therefore offers a significant reduction in the lighting intensity for substantial parts of the site, especially during the summer periods when it is much needed, as a result of the increased density and regularity of the proposed tree plantings and with positive contributions to the expected perceived temperatures and conditions of glare as they affect user comfort. Moreover, in the scenario whereby all trees were removed, on June 21st at 12:00 the lighting levels were at 15000+ (lux) for 100% of the site, compared to the maximum 12000 (lux) on 33% of the site, after two rows of trees were planted along the Makariou thoroughfare. An important reduction to light level intensity was also observed on March 21st at 12:00 where the drop is from a 15000+ (lux) maximum on 40% of the site down to 8000+ (lux) and 6000 (lux) values, on 40% and 47% of the site, respectively.

**3.2 Materials contribution to perceived temperatures**

In the context of this study six materials were studied, which were later consolidated into three main categories: asphalt, limestone pavers and brick pavers, Figures 9 & 10 shown below.



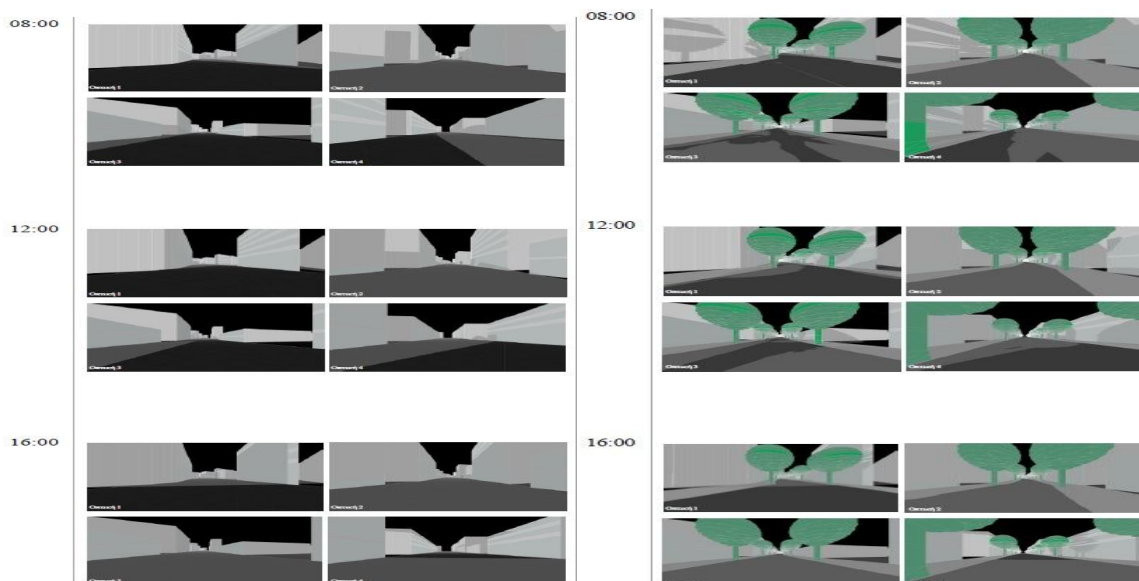
**Figures 9 & 10:** Investigation of different material pavers and thermal analysis

The use of these materials in the simulation was also examined during the three selected periods in the year, the three times of day and at various elevations on and above street level, as mentioned before. The simulated data indicate that for all three categories of materials, there is a perceptible temperature increase as we rise above street level. For example, in the case of asphalt there is a cumulative increase of 40-50% of the site, in the case of the limestone pavers 50-60% of the site and in the case of the brick pavers 30-40% of the site. In all the cumulative temperature increase along the length of the Makariou thoroughfare is anywhere between 30% and 60% as we rise above street level.

In the case of the brick pavers the temperature fluctuation range were between 21.52 and 21.60+ degrees Centigrade on December 21st and on March 21st and between 26.60+ and 27.75+ degrees Centigrade on June 21st. In the case of the limestone pavers and asphalt, these two groups had similar ranges of fluctuation, measuring between 21.00 and 21.05 degrees Centigrade for December 21st and March 21st and between 25.50+ and 27.20+ degrees Centigrade for June 21st. Taking into account the fifteen reference points along the corridor, it is noted that the difference in values between the limestone pavers on one hand and the asphalt and brick pavers on the other amounts to a 10-20% decrease for the latter over the former. The group of limestone pavers, which includes granite and concrete blocks in its category, is shown that there may be up to 1.5 degrees Centigrade difference observed between the lower values for the asphalt and the brick pavers and the higher values observed in the case of the limestone pavers.

**3.3 Tree planting contribution to user thermal comfort**

The effect of tree planting on user thermal comfort, Figures 11 & 12 shown below, as expressed by the data collected in terms of temperatures at 0.60m and 1.80m above street level was carried out on the previously discussed scenarios involving different material palettes with regards to the street paver alternatives.

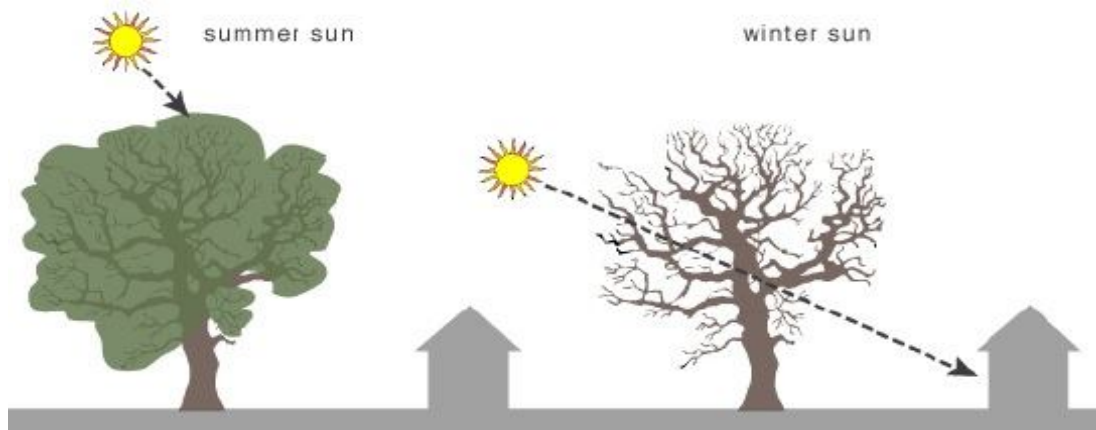


### Figures 11 & 12: Comparison before and after tree planting at key locations

The proposed tree planting sequence, which forms part of a future redevelopment strategy for the Makariou thoroughfare, was first examined for June 21st during the three times of day as mentioned before. The data shows a reduction in the temperature readings after the planting of trees of between 30-40% of the site in the case of the use of asphalt and limestone pavers. In the case of brick pavers for the period June 21st a reduction of 0.35 degrees Centigrade was noted for the 08:00 time slot and 0.05 degrees Centigrade for the 12:00 and 16:00 time slots. In an alternate example, utilizing a matched rather than a staggered sequence for the tree plantings, the temperature drops were in the range of 0.02-0.03 degrees Centigrade for a percentage difference compared to the base case of the existing thoroughfare of between 7-20%, thereby indicating tree planting as a very effective controller of ambient temperature and therein of thermal user comfort.

### 4 Concluding observations and recommendations

In all, both the inclusion of tree planting in matched or staggered formation and the careful choice of materials for the future street pavers of the thoroughfare constitute important factors in differentiating ambient temperature, perceived lighting levels and shading in the redeveloped scheme aspiring to improved user comfort over the current existing conditions. The right choice of deciduous tree such as the sycamore, which has been used for this simulation and which is included in these recommendations (and which has the added advantage of acting as a wind breaker during the winter northwesterly breezes) Figure 13 shown below, as well as the right combination of a material palette (which includes the limestone pavers grouping with the addition of granite and concrete blocks), as it pertains to the paving of the thoroughfare, have, as has been shown, the ability to moderate conditions in favor of achieving improved user thermal comfort in these regional conditions.



**Figure 13: Choice of deciduous trees, e.g. sycamore along thoroughfare.**

The study outlined above resulted from simulations that wish to inform the spatial and material design and landscape architecture treatment of the Makariou thoroughfare in Cyprus. The case study presented, however, is probably pertinent beyond the borders of this island country and within the geographic context of the Eastern Mediterranean region. Ecotect results have noted a much needed temperature rise up to 1.5 degrees Centigrade for the periods December 21st and March 21st given the proposed redevelopment strategies, whereas in the summer the difference between the existing situation and proposed redevelopment scenarios shows a much needed 0.50 degree Centigrade drop in favor of the redevelopment proposal.

More specifically for the December 21st and March 21st periods at the 12:00 time slot, the temperature readings were 22.65+ degrees Centigrade (at 0.60m for 33% of the site and at 1.80m for 53% of the site) and 22.50+ degrees Centigrade (at 1.80m for 47% of the site), respectively for the future redevelopment of the thoroughfare, whereas for the existing situation the readings were 21.05+ (at 1.80m for 40% of the site) for both periods stated above. During the summer period, wherein higher temperatures are being recorded, the values noted for the existing situation for the period June 21st at 16:00 were 27.15 degrees Centigrade (at 0.60m for 40% of the site and at 1.80m



for 33% of the site), whereas for the future redevelopment scenario the much needed lower recorded values were 26.71degrees Centigrade (at 0.60m for 33% of the site and at 1.80m for 40% of the site).

These observations indicate that the environmental design strategies for the future redevelopment for the site increase user thermal comfort, by allowing for slightly higher temperatures over the existing conditions for the fall, winter and spring periods and for slightly lower temperatures during the summer period.

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