Seasonal thermal adaptability of shopping arcades in hot and dry climates. The case of Nicosia’s historic centre

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Abstract. ‘Traditional’ semi-open retail environments have recently received increasing scientific attention due to their ‘rediscovery’ as passive and low-energy architectural elements, which could promote sustainability in the urban realm. This is of particular importance when considering that fully-closed contemporary shopping centres constitute high-energy consuming spaces during the cooling period, in hot climates. The present study deals with the thermal behaviour of shopping arcades, a ‘traditional’ bioclimatic urban feature, in the hot and dry climate of Cyprus, by means of on-site air temperature recordings. The aim of this research is the bi-seasonal thermal performance assessment of this semi-open space, so as to inform energy retrofitting practices and promote bioclimatism in contemporary designs. The research shows that arcades were designed mainly to address the hot climatic conditions of the island. The sample tested achieved a significant daytime cool island up to 4.4K, during the cooling period. The best performance was achieved in arcades which presented minimum openings to envelope areas. In contrast, a daytime air temperature reduction which reached 2.1K, was observed in arcades during the heating period, indicating a negative thermal effect. Overall, the positive thermal contribution of arcades during the cooling period proved stronger than the negative thermal effect during the heating period.

1. Introduction

The predominance of fully-closed, conditioned and energy-intensive shopping centres, has recently renewed interest on ‘traditional’ passive and low-energy, semi-open retail prototypes, such as shopping arcades and covered street markets. Shopping arcades — i.e. covered passages, aligned with shops on either side, which were designed to introduce natural daylight, sunlight and air in the underdeveloped interiors of urban blocks — formed focal points for social interaction, entertainment and retail activity, mainly from the 19th until the mid-20th centuries, which marked the decline and abandonment of this building type at an international level. By providing moderated control over sun, wind and light, these semi-open spaces achieved favourable microclimatic conditions relying completely on passive means.

In the last decades, a number of studies redrew attention on arcades. These studies mainly dealt with the architectural history, social history, typology and conservation of arcades, rather than with thermal issues [1, 2, 3, 4]. Interestingly, the study of Andre Potvin [5] on the microclimatic environment of several – mainly glass-covered – arcades in London and Cardiff, addresses this subject. His research demonstrated that such spaces offer significant thermal advantages, particularly during the cold days of the heating period, compared to open streets, while they do not overheat during the cooling period despite their lightweight glass roofs. Other studies [6, 7] carried out on the thermal performance of semi-
open spaces, i.e. covered passages, in the context of the Mediterranean vernacular architecture, illustrated a cooling effect of such spaces over the external environment during the cooling period.

Overall, the microclimatic response of semi-open arcades still remains unexplored to a great extent and their thermal contribution and seasonal thermal response requires systematic documentation. In particular, the thermal performance of arcades with high-mass roofs – which are common in the hot climates of the Mediterranean region – remains poorly investigated up to now. This study intends to deepen the knowledge on the seasonal thermal behaviour of shopping arcades in the Mediterranean context. In order to investigate the thermal behaviour of arcades, a representative sample was selected in the historic centre of Nicosia, for seasonal microclimatic recordings. Seasonal monitoring was undertaken in order to capture the thermal benefits and limitations of arcades over the external environment during the cooling and heating period, and to investigate the impact of arcade geometry, orientation and surrounding built environment on microclimate dynamics. The study of the thermal behaviour of arcades in Cyprus, would inform and encourage energy retrofitting practices and promote energy efficiency policies regarding contemporary design applications.

2. Methodology
The research methodology was based on on-site air temperature measurements for a sample of 14 arcades (Arc_1 to Arc_14) in the historic centre of Nicosia, which constitutes a typical Mediterranean historic centre. The case study arcades have been selected over a sample of more than 50 arcades that were identified in the designated area, based on their representativeness, historical, social and architectural significance and accessibility. Case study arcades distribute around a small area, in the Southwest part of the historic centre, which shares common urban design and microclimatic characteristics. One data-logger was positioned in each case study arcade, except in arcades Arc_2, Arc_3 and Arc_7, which were recorded in two different spots (A and B) (Table 1). Data-loggers were positioned above average human height to ensure equipment safety, under shade for protection from incident solar radiation and, where possible, in the middle of the space. The measurements were undertaken for a full-year. In order to examine the seasonal thermal variations of the arcade type, representative monthly data of the cooling (August) and heating (January) period were further analysed. Continuous measurements of air temperature were carried out using HOBOT UX100-003 data-loggers. Complementary data of outdoor climatic conditions was obtained by a VantagePro weather station installed near the examined sites, at a height above the surrounding built environment. The analysis of results included the presentation of: (a) mean minimum and maximum air temperatures and mean air temperature fluctuations for the cooling and heating period, in order to estimate the level of seasonal thermal response of each arcade, over the outdoor environment and compared to the rest of the sample, and (b) median values of mean hourly air temperature differences between arcades and ambient conditions so as to assess the diurnal thermal pattern of arcades and especially to identify the magnitude and duration of seasonal cooling and warming effects within a 24-hour period. This research is now being followed by a more detailed investigation of 4 arcades (taking into consideration other meteorological parameters such as wind speed, globe temperature and relative humidity, as well as use which allowed a quantitative assessment of thermal comfort) in the framework of an ongoing PhD thesis.

3. Description of examined arcades
The examined arcades, built between early 20th century and 1970, are characterised by common materials, local techniques and various architectural styles. Depending on the period of construction, arcades were influenced by traditional, Neoclassical, British colonial, Art Deco and/or Modernist prototypes. The main materials used for their construction are thermally massive, i.e. local stone or concrete, in combination with local stone or brick. Case studies are built in a dense and compact urban fabric that limits openness to the sky. They offer a rich variety in terms of geometry, typology, orientation and level of exposure of the building envelope, though it can be noted that specific design tendencies are clearly identifiable (Table 1). More specifically, since they are directly related to the commercial routes of the historic centre which are mainly north-south oriented, the majority of the
examined sites have an east-west orientation, which is considered to be less favourable in terms of solar gains and solar control potential. In terms of typology, most of the examined arcades feature a linear straight passage which prevails in the Nicosia paradigm, while a limited number represent more complex forms, such as L-shaped and U-shaped layouts. The particularity of Nicosia’s arcades, in the way they have been developed in landlocked sites, is also examined through the analysis of Arc_4, Arc_5 and Arc_7. Interestingly, these arcades, due to reduced accessibility, are characterised by limited openings to the outdoor environment. The examined arcades have a moderate length (5.5–30.0m). They have high-mass roofs which predominate in the historic urban fabric, with the exception of a glass-covered arcade (Arc_12), which is also surveyed for comparison reasons. Their building envelope mainly has limited opening areas with direct exposure to the outdoors, due to the compact build form and high-mass roofs, which probably allows for enhanced protection from direct solar gains. The majority of arcades with the exception of Arc_10 and Arc_12 remain vacant or with limited shops in use and are empty of people apart from occasional passer-by. For this reason, the possible gains from people or shops is not considered to be a significant factor affecting thermal performance for most of the cases. Special conditions, however, were recorded in Arc_2B, Arc_9, Arc_10 and Arc_12. Arc_2B, Arc_9 and Arc_12 are exposed to air-conditioning units that are dumping warm air; Arc_10 benefits from the operation of fans; Arc_2B and Arc_12 are semi-climatised and Arc_10 is fully climatised during the heating period.

**Table 1. Sample images and architectural plans**

| Arc_1 | Arc_2 | Arc_3 | Arc_4 |
|-------|-------|-------|-------|
| ![Image](image1) | ![Image](image2) | ![Image](image3) | ![Image](image4) |
| Arc_5 | Arc_6 | Arc_7 | Arc_8 |
| ![Image](image5) | ![Image](image6) | ![Image](image7) | ![Image](image8) |
| Arc_9 | Arc_10 | Arc_11 | Arc_12 |
| ![Image](image9) | ![Image](image10) | ![Image](image11) | ![Image](image12) |
| Arc_13 | Arc_14 |
| ![Image](image13) | ![Image](image14) |

*Data-logger location*

4. Results

4.1. Thermal environment analysis
4.1.1. Air temperature monitoring results during the cooling period. The analysis of air temperature data during the cooling period, shows that arcades present lower mean maximum air temperatures (mT_max_arc) than the corresponding values of the outdoor environment (mT_max_out) (Table 2). Particularly, mT_max_out reaches 37.0°C, while mT_max_arc ranges between 33.0°C and 35.9°C for the sample tested. Mean temperature differentials are between 1.1K and 4.0K (Table 2). The positive cooling effect of arcades is related to the combined effect of the compact built environment, the high-mass roofs, walls and floors and the deep plan layout, which reduce solar gains. It is interesting to mention that the arcades oriented along the least desirable east-west axis, or within ±30° of due east-west (e.g. Arc_6, Arc_8, Arc_12, Arc_13), do not generally elevate temperatures, most probably due to the effective shading of the surrounding compact built environment. It is noted that mT_max_arc tends to be lower: (a) in the arcades that have been developed in landlocked sites, i.e. Arc_4, Arc_5, Arc_7A and Arc_7B, due to the limited direct openings of their building envelope to the outdoor environment and their favourable orientation in terms of solar control which moderates external environmental extremes, (b) in Arc_10, that benefits from the ceiling fans in operation which remove excessive heat and (c) in Arc_3B that benefits from an indirect cooling effect of the cooling units that operate in the adjacent shops. Particularly, the mT_max_arc ranges between 33.0°-34.1°C in Arc_4, Arc_5 and Arc_7, equals to 33.5°C in Arc_10 and to 33.8°C in Arc_3B, while for the rest of the sample ranges between 34.2–35.9°C. Interestingly, Arc_11 presents the highest mean maximum temperature (35.9°C), due to the fact that its roof is ineffectively insulated and is directly heated by the sun, in contrast to the other arcades that are thermally protected by the upper floors of the buildings. Arc_2B which is negatively affected by the air-conditioning units that are dumping warm air directly into the arcade, presents the second highest mean maximum temperature (35.8°C) despite its favourable north-south orientation in terms of solar protection.

In contrast, a negative warming effect is observed in all examined arcades when minimum temperatures occur. More specifically, the mT_min_out is 24.4°C and mT_min_arc ranges between 26.5°C and 28.9°C. This means that there is a temperature differential between 2.1K and 4.5K (Table 2). This negative warming effect can be attributed to the low sky view factor which reduces heat loss through net long-wave radiation to the sky, the thermally massive materials which emit the absorbed heat during daytime and to the reduction of the wind speed in the build environment. High night-time temperatures then, confirm the presence of an urban heat island effect that is intensified due to the sheltered design of arcades.

In terms of mean air temperature fluctuations (mT(var)), a ‘damping’ effect is evident in arcades compared to the external environment, indicating the microclimatic advantages of the arcades during the cooling period. In particular, mean outdoor temperature fluctuations (mT(var_out)) equals to 12.6°C, while the corresponding values of arcades lay between 4.5°C to 8.5°C. Mean air temperature fluctuation differentials are estimated between 4.1K and 8.1K. This ‘damping’ effect is mainly attributed to the thermally massive materials and the compact build form of both the arcades and the site which allows effective shading and absorption of solar heat. Thermal stability is much stronger in Arc_4 and Arc_5 due to the combined effect of additional parameters. In particular, Arc_4 has minimum opening areas to the outdoor environment and is protected by solar gains due to its north orientation; Arc_5 is effectively protected and shaded by the adjoining deep atrium.

4.1.2. Air temperature monitoring results during the heating period. The monitoring results of the entire heating period indicate a negative cooling effect, since the majority of arcades present lower mean maximum temperatures (mT_max_arc) than the mean maximum temperatures of the outdoor environment (mT_max_out). Arc_2B, Arc_12 and Arc_14 – which present slightly higher mean maximum temperatures compared to the corresponding values of the outdoor environment – are exceptions. Arc_10 is not included in this analysis because is fully climatised. The mT_max_arc in Arc_2B equals to 15.1°C, in Arc_12 and Arc_14 corresponds to 14.3°C, while mT_max_out reaches 14.2°C. The temperature increase in the cases of Arc_2B and Arc_12, is mainly attributed to the heat gains by conduction and convection from shops on either side of the arcades and/or by the fact that these spaces are semi-climatised. As for Arc_14, its south orientation combined with its short length, maximise solar gain potential, which in turn improves overall thermal behaviour during the heating period. The mT_max_arc for the rest of the samples, ranges
### Table 2. Summary of recorded air temperature data during the cooling and heating period

| Arc | Plan | Le. | Or. | DE | Po | mT<sub>max</sub> | mT<sub>min</sub> | mTc | T<sub>max</sub> | T<sub>min</sub> | T<sub>max受害</sub> | T<sub>min受害</sub> |
|-----|------|-----|-----|----|----|----------------|----------------|-----|-------------|-------------|----------------|----------------|
| Out. | | C | 37.0 | 24.4 | 12.6 | 39.9 | 22.7 |
| | | H | 14.2 | 5.3 | 9.0 | 18.2 | 0.8 |
| 1 | 8.9 | 202 | 5.5 | C | 34.2 (-2.8) | 27.4 (+3.0) | 6.8 | 36.0 | 25.7 | 1.7 – 4.0 | -3.6 – 2.0 |
| | | H | 13.9 (-0.3) | 8.6 (+3.3) | 5.3 | 16.7 | 4.5 | -2.3 – 2.3 | -4.3 – 2.1 |
| 2A | 19.7 | 90 | 8.7 | C | 35.6 (-1.4) | 27.8 (+3.4) | 7.8 | 37.6 | 25.7 | 0.3 – 2.4 | -4.6 – 2.8 |
| | | H | 13.5 (-0.7) | 8.3 (+3.0) | 5.2 | 16.3 | 4.1 | -2.7 – 3.5 | -4.0 – 2.4 |
| 2B | 24.1 | 180 | 10.3 | C | 35.8 (-1.2) | 28.1 (+3.7) | 7.7 | 38.1 | 26.0 | 0.0 – 2.2 | -5.0 – 3.0 |
| | | H | 15.1 (-0.9) | 9.7 (+4.4) | 5.4 | 17.3 | 4.8 | -3.9 – 1.3 | -5.8 – 3.3 |
| 3A | 16.5 | 158 | 7.8 | C | 34.7 (-2.3) | 26.5 (+2.1) | 8.2 | 37.2 | 24.4 | 1.2 – 3.1 | -2.9 – 1.5 |
| | | H | 13.8 (-0.4) | 8.1 (+2.8) | 5.7 | 17.0 | 3.0 | -1.5 – 1.8 | -4.6 – 1.5 |
| 3B | 22.5 | 67 | 10.3 | C | 33.8 (-3.2) | 28.3 (+3.9) | 5.5 | 35.5 | 26.4 | 2.0 – 4.7 | -4.9 – 2.6 |
| | | H | 14.2 (0.0) | 8.6 (+3.3) | 5.6 | 16.6 | 4.4 | -2.2 – 1.9 | -4.2 – 2.1 |
| 4 | 21.9 | 32 | 25.5 | C | 33.0 (-4.0) | 28.1 (+3.7) | 4.9 | 35.1 | 26.4 | 2.8 – 5.4 | -4.5 – 2.8 |
| | | H | 12.6 (-1.6) | 9.7 (+4.4) | 2.9 | 14.9 | 6.1 | -2.7 – 3.4 | -5.6 – 2.6 |
| 5 | 12.2 | 117 | 9.8 | C | 33.1 (-3.9) | 28.5 (+4.1) | 4.5 | 34.8 | 26.8 | 3.0 – 5.2 | -5.0 – 3.1 |
| | | H | 12.8 (-1.4) | 9.5 (+4.2) | 3.3 | 15.4 | 5.8 | -2.9 – 4.3 | -5.7 – 2.5 |
| 6 | 18.3 | 117 | 11.6 | C | 35.2 (-1.8) | 28.9 (+4.5) | 6.2 | 37.9 | 27.5 | 0.0 – 2.7 | -5.8 – 2.8 |
| | | H | 13.4 (-0.8) | 9.7 (+4.4) | 3.7 | 16.1 | 5.9 | -2.8 – 2.7 | -5.8 – 2.7 |
| 7A | 28.2 | 107 | 23.1 | C | 33.3 (-3.7) | 27.4 (+3.0) | 5.9 | 35.6 | 25.8 | 2.8 – 4.8 | -4.0 – 2.1 |
| | | H | 13.0 (-1.2) | 8.6 (+3.3) | 4.4 | 15.8 | 4.3 | -2.0 – 4.2 | -4.6 – 2.2 |
| 7B | 17.1 | 197 | 21.9 | C | 34.1 (-2.9) | 27.5 (+3.1) | 6.6 | 35.7 | 26.0 | 1.1 – 5.0 | -4.4 – 1.6 |
| | | H | 13.6 (-0.6) | 8.9 (+3.6) | 4.7 | 16.2 | 4.6 | -2.3 – 3.1 | -4.6 – 2.3 |
| 8 | 14.4 | 106 | 9.3 | C | 35.2 (-1.8) | 27.0 (+2.6) | 8.2 | 38.3 | 25.3 | 0.9 – 2.2 | -3.3 – 1.8 |
| | | H | 13.2 (-1.0) | 7.6 (+2.3) | 5.6 | 16.4 | 3.0 | -1.3 – 3.2 | -3.2 – 1.1 |
| 9 | 28.1 | 82 | 8.7 | C | 35.6 (-1.4) | 27.7 (+3.3) | 7.9 | 37.7 | 26.3 | 0.6 – 2.5 | -3.8 – 2.7 |
| | | H | 13.9 (-0.3) | 8.4 (+3.1) | 5.5 | 16.7 | 4.5 | -2.0 – 2.1 | -4.2 – 1.8 |
| 10 | 29.5 | 103 | 8.1 | C | 33.5 (-3.5) | 28.6 (+4.2) | 4.9 | 35.9 | 26.8 | 2.1 – 4.6 | -4.8 – 3.3 |
| | | H | mechanical heating | | | | | | |
| 11 | 30.0 | 295 | 31.0 | C | 35.9 (-1.1) | 28.9 (+4.5) | 7.0 | 38.8 | 27.1 | 0.4 – 1.7 | -6.1 – 3.0 |
| | | H | 13.3 (-0.9) | 8.4 (+3.1) | 4.9 | 16.5 | 4.3 | -2.5 – 2.4 | -4.2 – 1.0 |
| 12 | 27.7 | 99 | 13.3 | C | 35.2 (-1.8) | 28.6 (+4.2) | 6.7 | 37.5 | 27.0 | 0.5 – 2.7 | -4.7 – 3.3 |
| | | H | 14.3 (+0.1) | 9.5 (+4.2) | 4.8 | 16.6 | 5.4 | -2.6 – 2.8 | -5.1 – 2.9 |
| 13 | 18.4 | 98 | 8.5 | C | 34.8 (-2.2) | 27.4 (+3.0) | 7.5 | 37.1 | 25.8 | 1.4 – 2.9 | -3.5 – 2.0 |
| | | H | 12.4 (-1.8) | 7.5 (+2.2) | 4.9 | 15.4 | 3.1 | -1.5 – 4.4 | -3.3 – 1.0 |
| 14 | 11.5 | 158 | 6.6 | C | 35.5 (-1.5) | 27.0 (+2.6) | 8.5 | 37.7 | 25.3 | 0.1 – 2.6 | -3.5 – 1.9 |
| | | H | 14.3 (+0.1) | 8.0 (+2.7) | 6.3 | 17.3 | 2.7 | -2.1 – 1.6 | -3.9 – 1.5 |

*Length
*Orientation, Degrees from North
*Degree of Enclosure; DoE = ΣA<sub>area</sub>/ΣA<sub>open</sub>, ΣA<sub>area</sub>, Sum of all surface areas; ΣA<sub>open</sub>, Sum of opening areas
*Monitoring Period, C, Cooling Period; H, Heating Period

Shopping arcades developed in landlocked sites

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between 12.4°C and 13.9°C (Table 2). Differences in mean maximum air temperature between arcades and the outdoor environment vary from 0.3K to 1.8K. These unfavourable microclimatic conditions can be explained by the high-mass roofs, the compact surrounding urban fabric and the deep plan of arcades which enhance shading and minimise the potential for direct solar access and solar passive heating.

On the other hand, arcades demonstrate a positive thermal effect when minimum temperature occurs, as all examined arcades present higher mean minimum temperatures (mT_{min,arc}) than the outdoor environment (mT_{min,out}). More specifically, mT_{min,out} reaches 5.3°C, while mT_{min,arc} ranges between 7.5°C and 9.7°C (Table 2). Differences in mean minimum air temperature between arcades and the outdoor environment vary from 2.2K to 4.4K. This positive thermal effect can be explained by the compact build form, which reduces the thermal heat losses, the slow release of heat of thermal mass which warms up the space and the effective protection from cold winds.

Table 2 indicates that the mean air temperature fluctuation of arcades (mT_{fluct,arc}) is significantly lower compared to the air temperature fluctuation of the external environment (mT_{fluct,out}). The mT_{fluct,arc} varies from 2.9°C to 6.3°C, while mT_{fluct,out} equals to 8.9°C. This ‘damping’ effect ranges from 2.6K to 6.0K.

4.1.3. Thermal behaviour assessment during the cooling period. The results of median values of mean hourly air temperature differences between each case study arcade and the outdoor environment during the cooling period are shown in Table 3. It is demonstrated that all case study arcades present a daytime cool island, i.e. the arcade is cooler than the outdoor environment. More specifically, the cooling effect takes place during morning to noon hours, while in some cases it lasts until late afternoon hours. The daytime cool island occurs between five to nine consecutive hours. The cooling effect becomes highest during noon or early afternoon, i.e. between 12:00h and 15:00h, at the hottest time of the day. At this critical time of the day, in terms of thermal stress or comfort, the arcade achieves a significant mitigation of outdoor temperature extremes. The highest median air temperature differences of the sample ranges between 1.0K and 4.4K. It is noted that the cooling effect in the arcades developed in landlocked sites (Arc_4, Arc_5, Arc_7A, Arc_7B) is stronger (3.3–4.4K) due to the enhanced protection from the outdoor climatic extremes. Arc_10 also presents a significant outdoor temperature reduction (3.7K) due to the effective contribution of ceiling fans. The highest median value of mean hourly air temperature differences for the rest of the sample is reduced between 1.0K and 3.1K.

During the late afternoon, night-time and early morning hours, the arcades under investigation present a heat island, i.e. the arcade is hotter than the outdoor environment (Table 3). This unfavourable warming effect reaches a peak either during late night, midnight and after midnight hours, i.e. 22:00h, 24:00h, 01:00h and 03:00h, or during early morning time, i.e. 05:00h and 06:00h, when ambient temperatures are at a minimum. It lasts between 15 and 19 hours. The highest median values of mean hourly air temperature differences registered for the sample was found to be between 2.3K and 5.1K. It is noted that the highest intensity of the heat island effect occurs when human activity is rather limited and outdoor temperatures are relatively low and thus less critical in terms of thermal comfort.

A further quantitative analysis of the cooling and warming effects of various arcades shows that the night-time heat island effect is stronger and lasts longer compared to the daytime cool island effect, with the exception of arcades developed in landlocked sites, i.e. Arc_4, Arc_7A and Arc_7B (Table 3).

4.1.4. Thermal behaviour assessment during the heating period. The results of median values of mean hourly air temperature differences between each case study arcade and the outdoor environment during the heating period are shown in Table 3. As shown in the Table, the majority of arcades tested are cooler compared to the outdoor environment during morning, noon or even early afternoon hours. Only Arc_2B, Arc_3B and Arc_14, remain warmer than the outdoor environment throughout the day. When a negative daytime cooling effect exists, it lasts from as little as two hours, to as long as eight hours. The highest median value of air temperature differences is registered at late morning or noon, i.e. between 11:00h and 12:00h. Although solar availability is maximum at this time, it remains unexploited to a large extent in the case of arcades. The highest median hourly air temperature differences of the sample ranges between 0.3K and 2.1K.
Table 3. Summary of median values of mean hourly air temperature differences between the arcades and the outdoor environment during the cooling and heating period

| Arc | Plan | Lc (m) | Or (°) | DE | P | \( T_{\text{arc} - T_{\text{out}}} \) Cooling Effect | \( T_{\text{arc} - T_{\text{out}}} \) Warming Effect |
|-----|------|--------|-------|----|---|-------------------|-------------------|
|     |      |        |       |    |   | Hours (b) | Temperature (°C) | Max (b) | Hours (b) | Temperature (°C) | Max (b) |
| 1   | 2A   | 19.7   | 90    | 8.7 | C | 11:00–16:00 (5) | 0.1–1.4 | 13:00–14:00 | 16:00–11:00 (19) | 0.2–3.9 | 22:00 |
|     |      |        |       |     |   | H 10:00–13:00 (3) | 0.4–0.9 | 12:00 | 13:00–10:00 (21) | 0.7–3.2 | 04:00 |
| 2B  | 16.5 | 158    | 7.8   |     | C | 10:00–18:00 (8) | 0.1–3.1 | 13:00–14:00 | 18:00–10:00 (16) | 0.8–3.8 | 05:00–06:00 |
|     |      |        |       |     |   | H 0-hours | – | – | 24-hours | 1.0–3.3 | 06:00 |
| 3A  | 22.5 | 67     | 10.3  |     | C | 10:00–18:00 (8) | 1.3–3.8 | 14:00 | 18:00–10:00 (16) | 0.3–4.1 | 06:00 |
|     |      |        |       |     |   | H 10:00–16:00 (6) | 0.5–1.7 | 12:00 | 16:00–10:00 (18) | 0.4–4.2 | 06:00–07:00 |
| 4   | 21.9 | 32     | 25.5  |     | C | 10:00–18:00 (9) | 1.3–4.4 | 13:00–15:00 | 18:00–10:00 (15) | 0.7–3.8 | 06:00 |
| 5   | 12.2 | 117    | 9.8   |     | C | 10:00–18:00 (8) | 1.3–3.8 | 14:00 | 18:00–10:00 (16) | 0.3–4.1 | 06:00 |
| 6   | 18.3 | 117    | 11.6  |     | C | 11:00–17:00 (6) | 0.6–1.7 | 14:00 | 17:00–11:00 (18) | 0.6–4.7 | 06:00 |
| 7A  | 28.2 | 107    | 23.1  |     | C | 10:00–14:00 (4) | 0.1–0.6 | 12:00 | 14:00–10:00 (20) | 0.2–3.4 | 04:00–07:00 |
| 7B  | 17.1 | 197    | 21.9  |     | C | 10:00–17:00 (7) | 0.3–1.9 | 14:00 | 18:00–09:00 (17) | 0.3–3.0 | 06:00 |
| 8   | 14.4 | 106    | 9.3   |     | C | 10:00–16:00 (6) | 0.2–1.3 | 12:00 | 16:00–10:00 (18) | 0.4–2.5 | 07:00 |
| 9   | 28.1 | 82     | 8.7   |     | C | 10:00–15:00 (5) | 0.4–1.6 | 13:00–14:00 | 15:00–10:00 (19) | 0.1–3.5 | 06:00 |
| 10  | 29.5 | 103    | 8.1   |     | C | 10:00–18:00 (8) | 0.1–3.7 | 14:00 | 18:00–10:00 (16) | 0.6–4.3 | 06:00 |
| 11  | 30.0 | 295    | 31.0  |     | C | 10:00–16:00 (6) | 0.4–1.8 | 12:00 | 16:00–10:00 (18) | 0.4–5.1 | 22:00–24:00 |
| 12  | 27.7 | 99     | 13.3  |     | C | 11:00–17:00 (6) | 0.1–1.5 | 13:00–14:00 | 17:00–11:00 (18) | 0.8–4.2 | 06:00 |
| 13  | 18.4 | 98     | 8.5   |     | C | 09:00–17:00 (8) | 0.1–2.4 | 13:00 | 17:00–09:00 (16) | 1.0–3.1 | 22:00–01:00 |
| 14  | 11.5 | 158    | 6.6   |     | C | 10:00–16:00 (6) | 0.2–1.1 | 14:00 | 16:00–10:00 (18) | 0.1–2.8 | 06:00 |

\(^{\text{a}}\)Length, \(^{\text{b}}\)Orientation, Degrees from North

\(^{\text{o}}\)Degree of Enclosure; DoE = \(\Sigma A_{\text{arc}}/\Sigma A_{\text{open}}\); \(\Sigma A_{\text{arc}}\), Sum of all surface areas; \(\Sigma A_{\text{open}}\), Sum of opening areas

\(^{\text{c}}\)Monitoring Period, C, Cooling Period; H, Heating Period

\(^{\text{d}}\)Based on median values

\(^{\text{e}}\)Shopping arcades developed in landlocked sites
Interestingly, a reverse phenomenon is observed from early afternoon, or in some cases late afternoon to morning hours, where arcades are warmer than the outdoor environment. This positive warming effect is much appreciated during the heating season, especially at these coldest hours of the day. The heat island occurs between 16 and 22 consecutive hours. However, by the time that this beneficial warming effect is at a maximum, the human activity within the spaces tested is significantly declining. In particular, the heat island intensity becomes highest a few hours after midnight, i.e. at 01:00h, 02:00h, 03:00h and 04:00h, or early in the morning, i.e. at 05:00h, 06:00h and 07:00h. The highest median value of mean hourly air temperature differences registered, was found to range between 2.2K and 4.9K. A comparative analysis shows that the heat island effect is stronger and lasts longer compared to the daytime cool island.

5. Discussion and Conclusions
Despite the restricted consideration of other than air temperature parameters in the framework of this research, which could allow a quantitative assessment of thermal comfort, some interesting outcomes were derived. Specifically, research results reveal that arcades in Nicosia were clearly designed to mainly address hot summer climatic extremes, rather than cold winter conditions, demonstrating a medium seasonal response. The hot climatic context of the island justifies this research outcome. The study revealed a positive daytime cool island in arcades during the cooling period at the hottest time of the day, which enables a significant moderation of thermal stress. Arcades which are characterised by limited opening areas to the outdoors proved to perform best during the cooling period. In addition, it is concluded that design features such as the high-mass roofs, deep shady atriums and the non-direct solar exposure of the roof – i.e. the coverage of the roof by upper floors – as well as the compact urban fabric, offer adaptability to the hot climate of the island. The operation of ceiling fans has also proved to be effective in moderating temperature extremes and fluctuations, while the negative impact of air-conditioning units has been also documented. During the heating season, it has been documented that the daytime bioclimatic potential of such urban and architectural elements is rather limited, mostly due to the shading effect. Thermal improvements need to be considered to tackle winter cold. However, it is noted that internal heat gains from shops on either side of arcade proved to be a significant source of heating. Overall, thermal differentials increase from the heating to the cooling periods. In particular, maximum temperature differentials range between 0.3–1.8K, and 1.1–4.0K during the heating and cooling season respectively. In line with this, the highest median value of mean hourly air temperature differences (i.e. when the arcade is cooler than the outdoor environment) ranges between 0.3–2.1K and 1.0–4.4K during the heating and cooling seasons respectively. This means that the cooling effect of arcades is stronger during the cooling period, where this effect is considered to be positive. These results document that the positive thermal contribution of arcades during the cooling period is stronger than their negative thermal effect during the heating period. This rather strikingly illustrates the positive bioclimatic effect of arcades.

References
[1] J. F. Geist, Arcades: the history of a building type, The MIT Press, 1989.
[2] M. MacKeith, The history and conservation of shopping arcades, Mansell Pub, 1986.
[3] M. MacKeith, Shopping arcades: a gazetteer of extant British arcades, 1817-1939, Mansell Publishing, 1985.
[4] B. Plevoets and K. Van Cleempoel, "Assessing authenticity of nineteenth-century shopping passages," Journal of Cultural Heritage Management and Sustainable Development, pp. 135-156, 2011.
[5] A. Potvin, "The arcade environment," Architectural Research Quarterly, vol. 2, pp. 64-79, 1997.
[6] E. Andreou and K. Axarli, "Investigation of urban canyon microclimate in traditional and contemporary environment. Experimental investigation and parametric analysis," Renewable Energy, vol. 43, pp. 354-363, 2012.
[7] M. Sinou and K. Steemers, "Urban space - thermal analysis of case studies," in WIT Transactions on Ecology and the Environment, 2003.