Microclimatic quality of urban routes and pedestrian behavior in arid zones case of the city of Biskra, South-East Algeria

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Received 17 April 2022
Revised 27 May 2022
14 August 2022
15 November 2022
Accepted 18 November 2022

Abstract

Purpose – The purpose of the study is to implement a methodology intended to identify the links between the microclimatic quality of urban routes and the behavior of pedestrians. This document will open up new opportunities for the development of urban open spaces and facilitate decision-making for urban decision-makers.
Design/methodology/approach – The methodology intended to identify the links between the microclimatic quality of urban routes and the behavior of pedestrians is deployed in two stages. The first stage represents a microclimatic characterization of the pedestrian routes. The second step represents a behavioral characterization of these same journeys, based on the on-site video observation of the pedestrians.
Findings – The analysis of the results obtained by applying this method shows that the physical factors of the urban environment in the two climatic seasons (winter, summer) significantly influence the choice of routes, the percentage of route use, the speed of travel and the frequency of user stops.
Originality/value – The authors have recently observed that the issue of the influence of microclimatic factors on the behavior of pedestrians, and more particularly their movements, has only rarely been addressed. It is therefore in this context that the authors would like to provide, through this article, some technical solutions for analysis and characterization as well as some answers to the problem of the influence of microclimatic factors on pedestrian movements.

Keywords Public space, Microclimatic characteristics, Pedestrian routes, User behavior
Paper type Research paper

1. Introduction

Recently, in the face of the rise in power of motorized travel modes, an increase in the number of work on the influence of environmental factors on walking practice has begun (Liang *et al.*, 2020; Seneviratne and Morrall, 1985; Burden, 1999; Willis *et al.*, 2004). In particular, they have sought to identify the factors that might favor walking in urban areas as an alternative mode of travel, since it has the advantage over other modes of travel of being non-polluting and beneficial to health. Most of this work comes from the fields of public health, ecology, and geography and road safety. In addition, in the field of urban planning, designers pay increasing attention to the influence of the morphological, aesthetic and functional properties of the built environment on the comfort and nature of pedestrian's activities in public spaces (Benedetta *et al.*, 2021; Nikolopoulou *et al.*, 2001). Some of this work argues for the need to adjust urban planning to the spatial and the environmental pedestrians needs, they insist that an urban space should be consistent with the expectations of pedestrians. Outdoor public

Frontiers in Engineering and Built Environment
Vol. 3 No. 2, 2023
pp. 93-107
Emerald Publishing Limited
e-ISSN: 2634-2502
p-ISSN: 2634-2499
DOI 10.1108/FEBE-04-2022-0015

space plays an essential role in shaping urban daily life as being the place for social interaction and various activities, such as culture, entertainment and sport as well as commercial activities (Thorsson *et al.*, 2004). The fascinating and vibrant cities should accommodate diverse activities for the people by offering more desirable and attractive public spaces, so people can carry out their activities in relative comfort and safety while interacting, engaging in spectacles and ceremonies, or just simply sitting or waiting (Jalaladdini and Oktay, 2012). However, it turns out that the designers do not always master these expectations, which sometimes leads to discrepancies between the characteristics of the produced spaces and the feelings of the users. In our opinion, these discrepancies result from the fact that the sensitive aspects, which characterize the relationship between man and his environment, are insufficiently taken into account in the design phase of projects. The problem of the microclimatic phenomena's and comfort on pedestrian behavior has so far only and rarely been addressed. It has mainly been the subject of studies focusing on a "static" analysis of microclimatic factors and their impact on the occupation of space and the nature of the activities carried out by users (Boumaraf and Amireche, 2018, 2020). However, judging by the number of recent publications, it can be seen that in the context of disciplines such as urban climatology and comfort in outdoor environments, work addressing this issue is currently in full swing. In addition, new lines of research are emerging, such as those concerning the consideration of psychological factors in the evaluation of the sensation of thermal comfort (Nikolopoulou *et al.*, 2001; Thorsson *et al.*, 2007). Nevertheless, some aspects related to the influence of environmental factors on pedestrian behavior remain insufficiently explored. We found that the problem of the influence of microclimatic factors on the behavior of pedestrians, and more particularly their movements, has rarely been discussed. It is in this context that we would like to bring, via this article, some technical solutions for analysis and characterization as well as elements of answers to the problem of the influence of microclimatic factors on the movements of pedestrians.

2. Study sites

To achieve the objective of this study, we selected a site, which is located in a hot arid climatic zone. As a study site, we have chosen an urban public place, the course of Martyrs, which is located in Biskra city. That city is situated in the South-East of Algeria, its geographical position is limited between 34.8° to the North and longitude 5.73° to the East in an area estimated at 21509.80 Km^2.

2.1 Presentation and description of the martyrs' course

The site, where the observations took place to collect behavioral and microclimatic data, is the Martyrs' Course. It is a popular meeting place due to its location and shape and its square is about 80 m long and 30 m wide, Bordered by a row of buildings on both sides. The courtyard is characterized by the presence of palm trees about 6 m high, eucalyptus trees about 8 m high, a mixed mineral and vegetal ground treatment with a paving of marble, red brick and concrete Plate 1.

3. Methodology

The methodology, to identify the links between the microclimatic quality of urban routes and pedestrian behavior is deployed in two stages.

3.1 Microclimatic characterization of pedestrian routes

We made our measurement under anticyclonic weather conditions. The weather was sunny with clear skies, with little or no wind. Measurements of the climatic parameters were

Plate 1.
Course of the Martyrs (Biskra)

taken by a portable weather station, which was mounted on an aluminium trolley with a Campbell Scientific CR800 Data Logger, and five sensors (complying with ISO 7726 1998) mounted on a telescopic pole at a height of 1.75 m, to represent the average height of a pedestrian. Environmental monitoring included T air and RH (using a CS215 probe with white radiation shield), T globe (CT100 probe), wind speed (two-dimensional ultrasonic anemometer) and illumination (Skye luxmeter). The aim of this phase is to describe the pedestrian routes from the point of view of their microclimatic features. To do this, we have developed an analysis and display tool to implement the different components of this characterization phase. The data managed in this analysis tool come from two sources, the simulation software SOLENE for the simulation of shadows and solar radiation and ENVI-MET for the thermo-radiative, aeraulics and bioclimatic simulations. The day of measurement and observation is therefore organized as follows.

3.1.1 First session 8h00–09h00.

(1) Climatic measures between 08:00 and 08:30.

(2) Video recordings between 08:30 and 09:00.

3.1.2 Second session 12:00–13:00.

(1) Climatic measures between 12:00 and 12:30.

(2) Video recordings between 12:30 and 1:00 p.m.

3.1.3 Third session 17h00–18h00.

(1) Climatic measures between 17:00 and 17:30.

(2) Video recordings between 5:30 and 6:00 p.m.

3.1.4 Fourth session 19:00–20:00.

(1) Climatic measures between 19:00 and 19:30.

(2) Video recordings between 7:30 and 8:00 p.m.

3.2 Characterization from the behavioral point of view

A behavioral characterization of these same pathways, based on the video observation on site of the behaviors taking into account the pedestrian trajectories, the average speed of travel as well as the duration of stops made by pedestrians. We selected three categories of stop duration on the three routes, which we observed on the martyrs' course. To define them, we timed the time taken by people who made stops during both seasons (summer, winter); see Table 1, which illustrates the three categories of average duration of stops made by pedestrians. It is necessary to report trajectories, trying to be as accurate as possible. For this purpose, the angle of vision of the camcorder should allow a global view of the space concerned by the study. Anyone passing in front of our field of vision was observed, in total, we observed 1,444 people in the entire square, of which 971 (67.24%) people during the hot period and 473 (32.76%) people during the cold period. It should also be noted that we will only be interested in pedestrians walking alone through the space. Indeed, in multi-person journeys, other factors, particularly of a "social" nature, may influence the decision making and the way in which pedestrians move, as they may tend to imitate the behavior (in terms of route's choice or stops, for example) of the people accompanying them. Three main routes (paths) observed (filmed on site and then viewed). The paths made up of block grouping traveled by pedestrians on the martyrs' course. By noting the number of subjects observed on the different routes in the two seasons, we are able to deduce the percentage of use of each route.

4. Correlation between microclimatic data and the space use

We have put in parallel, at the levels of Tables 4 and 5, the climatic and behavioral data of the three routes (ROU1, ROU2 and ROU3) in the two climatic seasons (winter, summer), with the aim of comparing them and checking whether there is any correspondence or discrepancy between the behavioral data of the three routes and the microclimatic measurements taken in each session.

4.1 Spatial and temporal coordination of microclimatic and the behavioral data

We applied to the plan of the course of martyrs a partition represented graphically by a rectangular block grid and identified by a numerical marker; see the application of the block grid on the martyrs course in Figure 1. Each block measures (20×10) m, i.e. 200 m^2. Thus, we

Table 1.
The three categories of duration of stops made by pedestrians

Categories of stops	Duration of stops/minute
Short stop	Less than 5 min
Medium-length stop	Between 5 and 10 min
Long stop	More than 15 min

had 12 blocks on the course studied. By grouping together, the adjacent rectangular blocks we can form the courses (the trajectories).

5. Results

5.1 Results of the microclimatic analysis hot period

5.1.1 First session. During this first measuring session, the space was divided between sun and shade. The shadows casted by the palms and eucalyptus trees coincided with their alignment on the square Plate 2, which resulted in two shaded paths, the first path (ROU1) represents blocks N1, N4, N7 and N10 on the east side of the martyrs' course and the second path (ROU2) represents blocks N3, N6, N9 and N12 on the west side of the martyrs' course and a central path (ROU3) represents blocks N2, N5, N8 and N11 in the sun. The blocks N1, N4, N7 and N10, the blocks N3, N6, N9 and N12 have high values compared to the other blocks opposite them. This is due to the fact that the blocks in the central path are exposed to the sun. We can also see that the difference between air temperature and global temperature is increasing in the central area. In block N2, the difference between Tg and Ta is 1.7 °C; in block N5, it is 1.9 °C, in block N8, which represents the café, it is 1.4 °C; however, in block N11 it is 2 °C. This is always explained by the presence of the sun. It is the central path, which is invested by the sun in the morning. In its evolution, the humidity curve follows that of the global temperature. The humidity values in blocks N1, N4, N7 and N10 and N3, N6, N9 and N12 are higher than those in blocks N2, N5, N8 and N11 due to the presence of palm trees, eucalyptus and grass in these two parts of the urban space.

5.1.2 Second session. During the second session, almost the whole place was in the shade of the trees, except for blocks N2, N5 and N11 which were in the sunlight. This explains the high global temperature values recorded in these blocks (41.6 °C, 41.8 °C and 41.5 °C), with the exception of block N8 (40.4 °C) representing the café, which has a high global temperature value due to its well-shaded terrace Plate 3. The humidity of the air is lower than in the first

N10	**N11**	**N12**
N7	**N8**	**N9**
N4	**N5**	**N6**
N1	**N2**	**N3**

Figure 1.
Application of the grid of rectangular sectors for the Martyrs course

Plate 2.
Palm shadows and eucalyptus trees on the Martyrs' Course

Plate 3.
Shade on the café terrace

session; however, it remains the same. It is relatively higher in blocks N1, N4, N7, N10 and N3, N6, N9, N12.

5.1.3 Third session. During the third measurement session, the sun was on the south-west side of the square and the whole square was in the shade of the trees except for blocks N2, N5 and N11. These three points are located in the central part of the martyrs' course. They are the clearest points toward the sky. This explains the high global temperature values in these three blocks (42.7 °C, 42.6 °C and 42.5 °C). The dry air temperature is relatively homogeneous in all points. The lowest dry air temperature value was recorded in blocks N1, N4, N7 and N10 (37.3 °C, 37.6 °C, 37.5 °C and 37.4 °C) and blocks N3, N6, N9 and N12 (37.4 °C, 37.5 °C, 37.3 °C and 37.4 °C) the highest value was recorded in block N11 (42 °C). The relative air humidity kept the same zigzag profile. It is higher in blocks N1, N4, N7 and N10 (44.7 °C, 44.9 °C, 44.8 °C and 44.6 °C) and blocks N3, N6, N9 and N12 (44.5 °C, 44.8 °C, 44.7 °C and 44.6 °C) than in blocks N2, N5, N8 and N11 (33.4°C, 33.7 °C, 33.5 °C and 33.3 °C) located on the central aisle. This is due to the fact that this part of the square remained sunny all morning.

5.1.4 Fourth session. During the last session, almost the whole place was in the shade. Only blocks N2, N5 and N11 (43.7 °C, 43.8 °C and 43.7 °C) were in the sun, which explains the high global temperature values in these blocks. Blocks N1, N4, N7, N10 and blocks N3, N6, N9 and N12 had higher humidity values than the other blocks.

5.2 Results of the microclimatic analysis cold period

5.2.1 First session. During the first measurement session, all measurement blocks were in homogeneous conditions. There was still no sun on the square. It appeared during the measurement session. The points on the central aisle N2, N5, N8 and N11 show significantly higher values of globe temperature (11.5 °C, 11.7 °C and 11.6 °C) and dry air temperature (11.1 °C, 11.3 °C and 11.4 °C) than the two other sides of the square N1, N4, N7, N10 and N3, N6, N9, N12. This is due to the fact that these points are in the sun and to the reflective character of the marble floor in the central part of the public space. On the other hand, the relative humidity is higher on the side of blocks N1, N4, N7 and N10 (69.5%, 70%, 69.8% and 69.7%) and blocks N3, N6, N9 and N12 (69.9%, 70.1%, 70.3% and 70%) than the central part of blocks N2, N5, N8 and N11 (67.1%, 67.3%, 68.4% and 67.2%). We also notice that the three values of Ta, Tg and RH% of the blocks N3, N6, N9 and N12 located on the east side of the square are getting closer. This is only due to the fact that this part of the square has a concrete floor treatment, different from the west side of the square, which is made of red brick. Blocks N1, N4, N7 and N10 could not benefit from the warmth of the sun, which appeared on the east side of the square blocks N3, N6, N9 and N12. The air speed values recorded on the side of blocks

N1, N4, N7 and N10 and blocks N3, N6, N9 and N12, are higher than blocks N2, N5, N8 and N11 which represents the central square.

5.2.2 Second session. During the second session, the whole central part of the martyrs' course was in the sun. The difference between global temperature and air temperature obviously increased in this part of space. The difference between the west side blocks N1, N4, N7 and N10 and the east side blocks N3, N6, N9 and N12 is still unclear. The highest value of global temperature was recorded in blocks N2, N5 and N11 and the lowest values in blocks N4, N7, N6 and N9. This is due to the density of the vegetation cover in these blocks. Blocks N2, N5 and N11 have been the most exposed to the sun and therefore show higher values of globe temperature and air temperature than blocks N1, N4, N7 and N10 and blocks N3, N6, N9 and N12. The humidity always has the same profile; the highest values are recorded in blocks N4, N7, N6 and N9, and the lowest values in blocks N2, N5 and N11. In other words, on the central side of the martyrs' course.

5.2.3 Third session. During the third session, all the space was shared between the shade and the sun. All the blocks were in homogenous conditions, in the shade of palm trees and trees. The air temperature, on the other hand, was relatively homogeneous in all the blocks. The relative air humidity values of blocks N1, N4, N7 and N10 on the west side and blocks N3, N6, N9 and N12 on the east side show higher values than blocks N2, N5, N8 and N11 in the central part of the course. The only exception is block N8, which represents the café terrace. On the other hand, the air velocity values in blocks N1, N4, N7 and N10 and blocks N3, N6, N9 and N12 are slightly higher than blocks N2, N5, N8 and N11, which represents the central part of the course.

6. Discussion of the microclimate analysis

6.1 Hot period

During the warm period, the air temperature increased as the day progressed. On the other hand, humidity decreased significantly. Concerning the global temperature, we can conclude that due to the shade of the palms and trees a certain homogeneity in the air temperature was noted at the blocks N1, N4, N7 and N10 and the blocks N3, N6, N9, N12. It is the exposure of the block to the sun "that makes the difference", the ca of the blocks in the central part of the course N2, N5, N8 and N11. Except for the first session where the space was divided between the sun and the shade, during the other sessions the shade of the trees made all the areas (blocks) homogeneous. The relative air humidity values of blocks N1, N4, N7 and N10 on the west side and blocks N3, N6, N9 and N12 on the east side show higher values in the morning, at noon and in the afternoon than blocks N2, N5, N8 and N11 in the central part of the course. The only exception is block N8, which represents the terrace. We can conclude that because of the vegetation the microclimate can be affected in many ways by reducing the air temperature compared to nonvegetated surfaces, providing shade and improving wind protection. The air speed is fluctuating. The highest values were recorded in blocks N1, N4, N7 and N10 and blocks N3, N6, N9 and N12 during the whole measurement day.

6.2 Cold period

During the cold period, as the day progressed, two large areas stood out. The first zone is the eastern and western part of the square, where there is vegetation and palm trees. The second zone is the central part of the square, bordered on both sides by the two rows of palm trees and trees towards blocks N2, N5, N8 and N11 of the martyrs' course. We recorded the lowest humidity values in the central part of the square compared to the two sides of the martyrs' course, east and west, due to the absence of vegetation and the exposure to the sun of this central part. In the afternoon, the highest values of global temperature and the lowest values of humidity were recorded in the central aisle of the square. The wind speed has the same evolution profile as the humidity in the morning and evolves in the opposite direction as soon as the sun appears. We also noticed that the highest humidity values were recorded in the two east and west sides of the martyrs' course, due to the vegetation in these two parts. Through the analysis of the microclimatic characteristics of the three courses, we confirmed the fluctuating nature of the climate parameters, especially the dry temperature and the air speed. The two measurements of the global temperature and air humidity best reflect the impact of the vegetation on the microclimatic measurements. We have found that the appearance of sunshine and the length of sunshine during the day play an important role in creating microclimatic dissimilarities between the different routes in the public space. We also note that the microclimatic differences are largely due to the differences in the urban design, especially the palm trees, trees, vegetation, orientation and the length of time, the routes are exposed to the sun. The nature of the materials also plays an important role. We also note that the shade of the trees contributes to the homogeneity of the climatic conditions on the martyrs' course.

7. Behavioral analysis results

7.1 Hot period

The behavioral observation of pedestrians on the martyrs' course presented in Table 2 allowed us to notice that during the summer period, the average speed of pedestrians on the ROU1 and ROU3 courses was higher than the average speed recorded on the ROU2 course. This is the same observation recorded during the first three observation sessions. The only exception is the fourth observation session, in which the speed of travel between the three routes ROU1 (0.80 m/s), ROU2 (0.90 m/s) and ROU3 (0.83 m/s) was similar. This observation is valid for all the observation sessions except for the fourth session, where the number of stops on the three routes ROU1, ROU2 and ROU3 is equal. Concerning the type of station during the first session, we have recorded short- and medium-duration stations on the ROU1 and ROU3 routes and one long duration stop on the central ROU2 route. This observation is also valid for the second session, but during the third and fourth sessions, only long duration stations were recorded on the three routes ROU1, ROU2 and ROU3. Regarding to the percentage of visitors, there is a considerable difference between the ROU1, ROU3 and central ROU2 routes Table 3.

7.2 Cold period

During the cold period, the behavioral observation of pedestrians on the martyrdom course presented in Table 2 revealed that the average speed of pedestrians on the central ROU2 course was lower than on the other two courses, ROU1 and ROU3, and this observation was recorded during the three sessions. We also noticed that during the three sessions the number of stops made on the central ROU2 route was higher than the two other routes on the West side, ROU1 and ROU3. Concerning the type of station, we recorded short duration stations on the two routes ROU1 and ROU3, However, on the central route, the registered stations were all long duration ones. This observation was recorded during the three sessions. The results of the three sessions showed a considerable difference between the central route ROU2 and the other two routes ROU1 and ROU3 Table 3.

8. Discussion of the mapping between microclimatic data and space use

The results provided by Table 4 show that during the first session**,** all the stations performed on the ROU1 browse (N1, N4, N7 and N10) and the ROU3 browse (N3, N6, N9 and N12) are of short duration. For this purpose, the used blocks are N4 and N7 on the ROU1 run and blocks

Session/summer	Routes	Speed mean (m/s)	Number of stops	Blocks used for stations	Duration average of stops (s)
First session (8h00–9h00)	ROU1 (N1, N4, N7, N10)	0.87	2	N4, N7	90–600
	ROU2 (N2, N5, N8, N11)	1.47	1	N8	1,500
	ROU3 (N3, N6, N9, N12)	0.84	3	N3, N6, N9	120–540–420
Second Session (12h00–13h00)	ROU1 (N1, N4, N7, N10)	0.90	3	N4, N7	480–420–720
	ROU2 (N2, N5, N8, N11)	1.24	1	N8	1,200
	ROU3 (N3, N6, N9, N12)	0.87	3	N6, N9	300–540–480
Third session (17h00–18h00)	ROU1 (N1, N4, N7, N10)	0.93	3	N1, N4, N7	1,020–1,320–1,080
	ROU2 (N2, N5, N8, N11)	1.50	1	N8	1,380
	ROU3 (N3, N6, N9, N12)	0.92	3	N3, N6, N9	1,080–2,220–2,280
Fourth session (19h00–20h00)	ROU1(N1, N4, N7, N10)	0.80	4	N1, N4, N7, N10	1,500–2,220–1,800–1,920
	ROU2 (N2, N5, N8, N11)	0.90	4	N2, N5, N8, N11	1,440–1,500–2,220–1,680
	ROU3 (N3, N6, N9, N12)	0.83	4	N3, N6, N9, N12	1,320–1,800–1,620–1,680

Session/winter	Routes	Speed mean (m/s)	Number of stops	Blocks used for stations	Duration average of stops (s)
First session (8h00–9h00)	ROU1 (N1, N4, N7, N10)	1.47	1	N1	60
	ROU2 (N2, N5, N8, N11)	0.81	4	N2, N5, N8, N11	2,220–1,800–1,200–1,920
	ROU3 (N3, N6, N9, N12)	1.50	1	N12	120
Second Session (12h00–13h00)	ROU1 (N1, N4, N7, N10)	1.47	1	N10	180
	ROU2 (N2, N5, N8, N11)	0.84	4	N2, N5, N8, N11	2,220–2,280–1,080–1,680
	ROU3 (N3, N6, N9, N12)	1.43	2	N3, N12	180–240
Third session (17h00–18h00)	ROU1 (N1, N4, N7, N10)	1.44	1	N7	90
	ROU2 (N2, N5, N8, N11)	0.84	4	N2, N5, N8, N11	2,220–2,280–1,020–1,920
	ROU3 (N3, N6, N9, N12)	1.47	1	N9	120

Table 2.
Behavioral data evaluated at the level of the courses in summer

N3, N6, N9 on the ROU3 run with a slightly higher station duration at block N7. We also recorded an average pedestrian speed of (0.87 m/s) and a percentage of 9.99% pedestrian traffic on ROU1. On the other hand, on the ROU3 route, we recorded an average travel speed of 0.84 m/s and a percentage of traffic of 8.34%. On the central ROU2 route (N2, N5, N8 and

Session/summer	Routes	Number of subjects observed on the route	Percentage of route use (PRU) (%)
First session (8h00–9h00)	ROU1 (N1, N4, N7, N10)	97	9.99
	ROU2 (N2, N5, N8, N111)	7	0.72
	ROU3 (N3, N6, N9, N12)	81	8.34
Second Session (12h00–13h00)	ROU1 (N1, N4, N7, N10)	102	10.50
	ROU2 (N2, N5, N8, N111)	11	1.13
	ROU3 (N3, N6, N9, N12)	127	13.07
Third session (17h00–18h00)	ROU1 (N1, N4, N7, N10)	108	11.12
	ROU2 (N2, N5, N8, N111)	15	1.54
	ROU3 (N3, N6, N9, N12)	121	12.47
Fourth session (19h00–20h00)	ROU1 (N1, N4, N7, N10)	130	13.40
	ROU2 (N2, N5, N8, N111)	47	4.84
	ROU3 (N3, N6, N9, N12)	125	12.88
Total		971	100 (%)

Session/winter	Routes	Number of subjects observed on the route	Percentage of route use (PRU) (%)
First session (8h00–9h00)	ROU1 (N1, N4, N7, 10)	5	1.06
	ROU2 (N2, N5, N8, 11)	147	31.08
	ROU3 (N3, N6, N9, N12)	7	1.48
Second Session (12h00–13h00)	ROU1 (N1, N4, N7, N10)	11	2.32
	ROU2 (N2, N5, N8, 11)	202	42.70
	ROU3 (N3, N6, N9, 12)	8	1.70
Third session (17h00–18h00)	ROU1 (N1, N4, N7, N10)	4	0.84
	ROU2 (N2, N5, N8, 11)	87	18.40
	ROU3 (N3, N6, N9, N12)	2	0.42
Total		473	100 (%)

Table 3.
Percentage of use of the routes in the two climatic seasons (summer, winter)

N11), only one long-duration station was set up, the block is used for this purpose and N8, which represents the café terrace. On this route, the average speed of pedestrians was (1.47 m/s) and the percentage of pedestrians using it was 0.72%. If we review the microclimatic measurements recorded during this session, the ROU1 (N1, N4, N7 and N10)

Session	Climate data					Behavior data			
						Speed mean (m/s)	Number of stops	(PRU) (%)	Duration average of stops (s)
First session	ROU1	N1	N4	N7	N10	0.87	2	9.99	90–600
	RH (%)	48.3	50	52	49.4				
	Tg(C°)	24.2	22.3	22.4	23				
	Ta(C°)	237	22	21.7	22.9				
	Va(m/s)	1.5	1.6	1.4	1.5				
	ROU2	N2	N5	N8	N11				
	RH (%)	39.8	39.9	40	39.7	1.47	1	0.72	1,500
	Tg(C°)	30.6	30.7	31.5	32				
	Ta(C°)	28.9	28.8	30.1	30				
	Va(m/s)	2.4	2.5	2.6	2.4				
	ROU3	N3	N6	N9	N12	0.84	3	8.34	120–540–420
	RH (%)	47.9	49.8	51.1	50				
	Tg(C°)	24.1	22.3	22	23.2				
	Ta(C°)	23.7	22	21.7	22.9				
	Va(m/s)	1.6	1.7	1.5	1.6				
Second session	ROU1	N1	N4	N7	N10	0.90	3	10.50	900–1,080–960
	RH (%)	44.7	44.9	45.3	43.8				
	Tg(C°)	36.2	36.6	36.5	36.3				
	Ta(C°)	35.7	35.3	35.2	35.6				
	Va(m/s)	1.3	1.1	1	1.2				
	ROU2	N2	N5	N8	N11	1.24	1	1.13	1,200
	RH (%)	34.5	34.7	35.1	33.9				
	Tg(C°)	41.6	41.8	40.4	41.5				
	Ta(C°)	40.9	40.8	40.7	40.8				
	Va(m/s)	1.9	1.7	1.6	2				
	ROU3	N3	N6	N9	N12	0.87	3	13.07	1,200–1,140–960
	RH (%)	44.4	44.7	44.8	43.5				
	Tg(C°)	36.3	36.2	36.4	36.3				
	Ta(C°)	35.6	35.9	35.8	35.7				
	Va(m/s)	1.4	1.1	1.2	1.3				
Third session	ROU1	N1	N4	N7	N10	0.93	3	11.12	1,020–1,320–1,080
	RH (%)	44.7	44.9	44.8	44.6				
	Tg(C°)	37.3	37.6	37.5	37.4				
	Ta(C^0)	36.8	36.7	36.5	36.6				
	Va(m/s)	1	1.2	1.1	1.2				
	ROU2	N2	N5	N8	N11	1.50	1	1.54	1,380
	RH (%)	33.4	33.7	33.5	33.3				
	Tg(C°)	42.7	42.6	42	42.8				
	Ta(C°)	41.1	41.3	41.4	41.5				
	Va(m/s)	1.7	1.9	1.8	1.6				
	ROU3	N3	N6	N9	N12	0.92	3	12.47	1,080–2,220–2,280
	RH (%)	44.5	44.8	44.7	44.6				
	Tg(C°)	37.4	37.5	37.3	37.4				
	Ta(C°)	36.7	36.4	36.5	36.3				
	Va(m/s)	1.1	1.3	1.1	1.2				
Fourth session	ROU1	N1	N4	N7	N10	0.80	4	13.40	1,500–2,220–1,800–1,920
	RH (%)	44.5	44.7	44.6	44.4				
	Tg(C°)	35.3	35.6	35.5	35.4				
	Ta(C°)	34.8	34.7	34.5	34.6				
	Va(m/s)	1.1	1.3	1.2	1.2				
	ROU2	N2	N5	N8	N11	0.90	2	4.84	1,440–1,500
	RH (%)	32.5	32.3	32.5	32.4				
	Tg(C°)	43.7	43.8	42.5	42.7				
	Ta(C°)	42.8	42.7	42.6	42.5				
	Va(m/s)	2	2.1	1.9	1.9				
	ROU3	N3	N6	N9	N12	0.83	4	12.88	1,320–1,800–1,620–1,680
	RH (%)	44.4	44.8	44.7	44.6				
	Tg(C°)	35.4	35.7	35.8	35.4				
	Ta(C°)	34.7	34.8	34.9	34.6				
	Va(m/s)	1.1	1.3	1.2	1.2				

Table 4.
Crossing of climatic and behavioral data in summer

Session	Climate data					Behavior data			
						Speed mean (m/s)	Number of stops	(PRU) (%)	Duration average of stops (s)
First session	ROU1	N1	N4	N7	N10	1.47	1	1.06	60
	RH (%)	69.5	70	69.8	69.7				
	Tg(C°)	9.9	10	10.1	10.2				
	Ta(C°)	9.6	9.7	9.8	9.9				
	Va(m/s)	1.1	1.3	1.2	1.3				
	ROU2	N2	N5	N8	N11	0.81	4	31.08	2,220–1,800–1,200–1,920
	RH (%)	67.1	67.3	68.4	67.2				
	Tg(C°)	11.5	11.7	10.2	11.6				
	Ta(C°)	11.1	11.3	9.7	11.4				
	Va(m/s)	1	1.1	1	1.1				
	ROU3	N3	N6	N9	N12	1.50	1	1.48	120
	RH (%)	69.9	70.1	70.3	70				
	Tg(C°)	9.8	101	10.2	10.4				
	Ta(C°)	9.7	9.8	9.9	10				
	Va(m/s)	1.2	1.3	1.4	1.3				
Second session	ROU1	N1	N4	N7	N10	1.48	1	2.32	180
	RH (%)	60.9	60.7	61	60.8				
	Tg(C°)	22.9	22.2	22.3	22.4				
	Ta(C°)	14.7	14.8	15	149				
	Va(m/s)	1	1.2	1	1.1				
	ROU2	N2	N5	N8	N11	0.80	4	42.70	2,220–2,280–1,080–1,680
	RH (%)	58.6	58.9	58.7	58.5				
	Tg(C°)	24.9	25	25.2	24.9				
	Ta(C°)	17.1	17.3	17.4	17.2				
	Va(m/s)	1.3	1.4	1.3	1.4				
	ROU3	N3	N6	N9	N12	1.51	2	1.70	180–240
	RH (%)	60.7	60.4	60.6	60.7				
	Tg(C°)	22.8	22.9	22.1	22.3				
	Ta(C°)	14.5	14.4	14.9	15				
	Va(m/s)	1	1.2	1	1.1				
Third session	ROU1	N1	N4	N7	N10	1.47	1	0.84	90
	RH (%)	61	61.5	61.4	61.1				
	Tg(C°)	22.7	22.8	22.9	22.5				
	Ta(C°)	14	14.3	14.2	14.1				
	Va(m/s)	1.2	1.1	1.2	1.3				
	ROU2	N2	N5	N8	N11	0.84	4	18.40	2,220–2,280–1,020–1,920
	RH (%)	57.4	57.4	57.6	57.3				
	Tg(C°)	24.1	24.3	24.4	24.2				
	Ta(C°)	16.3	16.4	16.5	16.2				
	Va(m/s)	1	0.9	1	1.1				
	ROU3	N3	N6	N9	N112	1.48	1	0.42	120
	RH (%)	60.8	61	60.9	60.7				
	Tg(C°)	22.8	22.9	22.7	22.5				
	Ta(C°)	141	14.3	14.4	14.3				
	Va(m/s)	1.1	1.2	1.3	1.2				

Table 5.
Crossing of climatic and behavioral data in winter

and ROU3 (N3, N6, N9 and N12) routes were in the shade of palm trees and it is at these two routes that we have the lowest values of global temperature and the highest values of relative air humidity. Only blocks N2, N5 and N11 were in the sun and it is in these points that we recorded the highest values of global temperature and the lowest values of relative air humidity.

During the second session, all the stations carried out on ROU1 (N1, N4, N7 and N10), ROU3 (N3, N6, N9 and N12) and ROU2 (N2, N5, N8 and N11) are long duration. The blocks used on the ROU1 run are N1, N4 and N7, on the ROU2 run the block N8 and at the end the PAR3 run are N3, N6 and N9. We have also recorded an average pedestrian speed of 0.90 m/s and a percentage of 10.50% pedestrian traffic on PAR1. On the other hand, on the ROU2 route, we have recorded an average speed a percentage of visitors of 1.13% and at the end of the ROU3 route, we recorded an average speed of 0.87 m/s and a percentage of visitors of 13.07%. During this second session, the central route was in the sun, with the exception of the ROU1 and ROU3 routes. These two routes had the lowest global temperature values. On the other hand, it is at the urban points N2, N5 and N11. The highest values of global temperature, air speed and relative humidity were found in the central section.

During the third session, the whole urban space was in the shade except the urban blocks N2, N5 and N11 of the central road. It is in these points that we recorded the most important values of global temperature. The stations during this session on the three routes are of long duration. However, the average station duration and the number of stops is higher for the ROU1 and ROU3 runs compared to the central run ROU2. We also recorded an average pedestrian speed of 0.93 m/s and a percentage of pedestrian use of 11.12% on the ROU1 route. However, on the ROU2 route, we recorded an average travel speed of 1.50 m/s and a percentage of visitors of 1.54% and at the end of the ROU3 route, we recorded an average travel speed of 0.92 m/s and a percentage of visitors of 12.47%. The air temperature and global temperature in measuring blocks N2, N5 and N11 were higher than those recorded on the west side ROU1 and east side ROU3 of the square which were in the shade of the palms. Contrastingly, the humidity is higher on the ROU1 and ROU3 routes compared to the central ROU2 route, which was in the sun.

During the fourth session, all the stations performed on the routes ROU1 (N1, N4, N7 and N10), ROU2 (N2, N5, N8 and N11) and ROU3 (N3, N6, N9 and N12) are long durations. For this, the blocks used are blocks N1, N4, N7, N10, N8, N11, N3, N6, N9 and N12. We also recorded on the route ROU1 an average speed of movement of pedestrians of 0.80 m/s and a percentage of attendance of 13.40%. Oppositely, on the route ROU3 we have recorded an average speed of movement of 0.83 m/s and a percentage of attendance of 12.88%. It is also in these routes ROU1, ROU3 where we noted the lowest values of globe temperature and the highest relative humidity values. Finally, on the walk ROU2, we recorded an average speed of movement of 0.90 m/s and a percentage of attendance of 4.84%. It was on the route ROU2 that we recorded at the level of urban blocks N2, N5 and N11 the highest values of dry air temperature and the lowest relative humidity values. During this session, the whole place was in the shade except the three blocks N2, N5 and N11. We notice that no station has been registered in these three blocks. Relative humidity was higher on the side of the routes ROU1 (N1, N4, N7, N10) and ROU3 (N3, N6, N9, N12), this is due to the density of the vegetation cover in these routes.

The results provided by Table 5 during the first session, ROU1 (N1, N4, N7 and N10) and ROU3 (N3, N6, N9 and N12) were used for short duration stations. The used blocks are N7 on the PAR1 run and N9 on the PAR3 run, but all the stations on the other blocks of the PAR2 run (N2, N5, N8 and N11) are long duration stations. We also recorded an average speed of pedestrians (1.47 m/s) and a percentage of visitors (1.06%) on the ROU1 route. However, on the ROU3, we recorded an average travel speed of 1.50 m/s and a percentage of visitors of 1.48%. On the central ROU2 route (N2, N5, N8 and N11), the average speed of pedestrians on this route was 0.81 m/s and the percentage of pedestrians using the route was 31.08%. If we review the microclimatic measurements recorded during this session, the ROU1 (N1, N4, N7 and N10) and ROU3 (N3, N6, N9 and N12) routes were in the shade of palm trees and it is at these two routes that we have the lowest values of global temperature and the highest values of relative air humidity. On the other hand, on the central walkway ROU2 (N2, N5, N8 and N11) was in the sun and it was in blocks N2, N5 and N11 that we recorded the highest global temperature values and the lowest relative air humidity values.

In the second session, we have recorded on the ROU1 browse (N1, N4, N7, N10) and only one short duration station was recorded; the block used for this is N10 and two short duration stations on the ROU3 browse (N3, N6, N9 and N12); the blocks used for this are N3 and N12 on the other hand on the central ROU2 run (N2, N5, N8 and N11) all the stations carried out on the blocks (N2, N5, N8 and N11) are of long duration. On the ROU1 route, we also recorded an average pedestrian speed of 1.48 m/s and a percentage of 2.32% pedestrian traffic. On the other hand, on the ROU3 route, we recorded an average speed of 1.51 m/s and a percentage of 1.70% pedestrian traffic. On the central ROU2 route (N2, N5, N8 and N11), the average speed of pedestrians on this route was 0.80 m/s and the percentage of pedestrians using it was 42.70%. If we go back to the microclimatic measurements, we find that the global temperature values show a clear difference between the west side of ROU1 (N1, N4, N7and N10) and the east side of ROU3 (N3, N6, N9 and N12) compared to the central ROU2 (N2, N5, N8, N11), it is more important on the side of the central ROU2. Humidity, on the other hand, has opposite values. It is higher on the ROU1 (N1, N4, N7 and N10) and ROU3 (N3, N6, N9 and N12) sides.

During the last session, blocks N7 on the ROU1 browse and N9 on the ROU3 browse were used for short duration stations, whereas blocks N2, N5, N8 and N11 on the ROU3 browse were used for long duration stations. We also recorded an average pedestrian speed of 1.47 m/s and a percentage of 0.84% pedestrian traffic on ROU1. On the other hand, on the ROU3 route, we recorded an average speed of 1.48 m/s and a percentage of 0.42% visitors. On the central ROU2 route (N2, N5, N8 and N11), the average speed of pedestrians on this route was 0.84 m/s and the percentage of pedestrians using the route was 18.40%. During this session, all the blocks of the ROU1 and ROU3 route were in the shade of palm trees. Dry air and global temperatures remained very homogeneous in these blocks of the square, except in blocks N2, N5, and N11 of the central ROU2 walkway, which were in the sun [. . ..] Air velocity and humidity values are higher on the west side ROU1 and east side ROU3.

9. Conclusion

In this article, we have presented a method of identifying the links between the moving pedestrians "behavior and the environmental quality of routes in an urban public space". The results, obtained by applying this method, show that the physical factors of the environment have a significant influence on the choice of routes, the percentage of route frequentation, the speed of travel and the frequency of users' stops. It is also noted that the thermal environment of urban routes and the design of the public space are important factors in the use. In order to use urban routes, when thermal conditions become too cold or too hot for comfort, people improve their comfort conditions by helping more favorable opportunities available in the place. Indeed, the routes identified as being relatively comfortable in summer, from the point of view of comfort indicators, are 12%–13% more frequented than the routes identified as less comfortable Table 3, and the routes identified as being relatively comfortable. In winter from the point of view of comfort indicators are 31%–42% more frequented than the routes identified as less comfortable Table 5. The methodology developed in this article can be applied in a relatively simple and effective way, in any public space. We wished to make method a tool for dialouge between all the actors acting in the urban environment. It is recommended to continue research on the microclimatic quality of urban routes and the behavior of pedestrians to be undertaken in the following areas:

(1) Further work needs to be done to cover more geographical areas within the hot arid climate, as this study covers only the city of Biskra. Such an expansion may generalize the findings of this study or explain any particularity associated with the sites of current study.

(2) Analyze and quantify, using a series of microclimatic simulations, the effect of the urban heat island phenomenon (ICU) on the comfort of pedestrians and their choice of routes in urban public spaces, in arid climatic zones.

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