ABSTRACT

Today, although most of the international research community considers climate change adaptation to be essential, there is limited knowledge on its concrete integration with contemporary placemaking. Yet, with the emergence of the adaptation agenda, the effects of urban climatology are continually coercing the need for concrete action to increase the climatic responsiveness of urban environments. This article is constructed upon a “Research for Design” approach, and focuses upon improving urban design guidelines by reviewing existing theoretical/empirical research on how pedestrian comfort levels can be addressed through public space design. The objective is to incorporate such qualitative and quantitative interrogations into a generic tool such as the “Place Diagram” by the PPS. A total of six intangible criteria, and six measurable attributes, are explored and structured in order to introduce new generic design considerations which can contribute to the responsiveness of urban outdoor spaces in an era of expected climate variability.

Introduction

The art of contemporary placemaking is one which draws upon the early teachings of authors such as Whyte (1980), Gehl (1987) and Carmona et al. (2003). These lessons were marked by the merging of not just interdisciplinarity, but that of different professional spheres. Through time, the process of placemaking has accompanied issues intrinsically associated with the physical, social, ecological, cultural and “spiritual” qualities of the urban realm. However, and adjoining such interdisciplinarity, new obstacles and issues are continually raising the need to rethink the process of placemaking.

The very conception of what makes a public space “successful” requires a continuous adjustment given the unrolling of obstacles presented before contemporary cities. In this article, the phenomenon of temperature escalations due to possible climate change shall be approached in order to identify how public spaces can meet such challenges both today, and in the future. It is here where new spheres such as climatology, biometeorology, and...
physiology raise new considerations in ensuring the comfort, safety and activity threads in a century which may witness increased occurrences/intensities of heat waves, temperature thresholds and urban heat island (UHI) effects.

Serving as an obstacle, however, and within the local scale, although there is a consensual need to act, there is often a lack of knowledge on how such adaptation measures can improve the experience and comfort of pedestrians in outdoor environments. For this reason, placemaking approaches such as the “Place Diagram” disseminated by the Project for Public Spaces require revision and require new considerations that aid local decision-making and design.

This article will be divided into three principal sections, the discussion of the existing diagram, the establishing of new qualitative/quantitative criteria and the respective restructuring of the diagram. Consequently, this draws upon the integration and organisation of new necessary “intangible” and “measurements” within a generic tool for contemporary placemaking in a century prone to potential impacts resultant of climate change.

The Place Diagram

Based on the work of Whyte (1980) and Jacobs (1961), the PPS have used techniques such as observation, surveys and interviews to study and transform public spaces into vibrant outdoor spaces that pedestrians enjoy (PPS 2000). Their work was considered to establish major groundwork in changing the way in which public spaces were built and planned. As
part of their placemaking process, the PPS stated that “[their] approach to placemaking is based on [their] belief that it is not enough to simply develop design ideas and elements to improve or develop a public space (...) Improvements need to reflect community values and needs” (PPS 2003a, 3). Thus, in the eyes of the PPS since its establishment in 1975, societal necessities play a crucial role in creating a vision around the places which are part of the daily life of pedestrians. As a result, and in an attempt to respond to the issues that communities face in urban contexts, the organisation launched the polemic question: “What makes a Great Place?”

To answer this question, and after evaluating thousands of public spaces worldwide, the PPS created a diagram which refers to the significance of four principal urban qualities: (1) Sociability; (2) Uses and Activities; (3) Access and Linkages; and lastly, (4) Comfort and Image (PPS 2003b). This is summed in their “Place Diagram” as shown in Figure 1.

The diagram departs from four key attributes which can be scrutinised by both qualitative (termed as intangible) and quantitative (termed as measurable) criteria. It is worth noting that the “Place Diagram” is a generalist approach to considering the qualities of a public space. For this reason, the intention of the diagram is not to lead to answers, but instead, to aid local designers and decision makers in considering general factors which compose that of a successful public space.

Today, one of the distinctive characteristics of the PPS is their involvement in linking communities with not only placemaking, but also place-keeping (Dempsey and Burton 2012). Once the PPS first started working with local communities, it was evident that a lot of information could be extracted from people that worked or lived close to the respective spaces. This user-based approach was also one that allowed local officials and designers to access a large database or “portfolio” of successful spaces, both in terms of public space design, but of community engagement as well. These respective “exemplar spaces” are those which proved to be analogous to the expectations/requirements of the surrounding communities with regards to overcoming a certain urban challenge.
However, and when looking into the future, it is here questioned – How can this user-based approach continue to meet the expectations and requirements of local communities in light of new urban challenges?

Within what is considered a “third modernity” where, “the contemporary society witnesses rapid transformations and, resultant of this evolution, the degree and velocity of this transformation is often underestimated (…) in the domain of Urbanism, such comprehension is even more challenging to appreciate due to the slow evolution of the edified fabric, and because of the comparatively small amount of new annual contributions to the existing fabric …” (Ascher [2001] 2010, 19, author’s translation), it is here argued that the “Place Diagram” needs to consider new factors in the light of the volatile urban climate until the end of the century. This being said, and although the physical attributes of public spaces may not have changed, they must nevertheless continue to reflect the values and needs of an ever evolving society. When regarding this evolution, although

...cities have grown gradually for hundreds of years, rooted in many years of experience and an intuitive feeling for human senses and scale (…) this knowledge was lost somewhere in the process of industrialization and modernization, which led to dysfunctional city environments for the important and yet ignored segment of city life on foot. (Gehl and Svarre 2013, 3)

Following this line of thought, if one is to consider public spaces to be a “founder of urban form, the space between buildings, that configures the domain of socialisation and ‘common’ experiences, and likewise of a collective community” (Brandão 2011, 34, author’s translation), then one must “recognise the important role that public spaces play in extreme temperatures/combatting climate change.” (CABE and Practitioners 2011, 3). For this reason, and when considering future horizons and the progressively ensuing opportunities presented for climate change adaptation, new deliberations must be made upon the ability of public spaces to: (1) contribute to the alleviation of impacts within the built environment; and, (2) incorporate adaptive means in their own design without sacrificing their existing positive attributes (illustrated by approaches such as the “Place Diagram”). Either way, this introduces new challenges for public space design, and presents the opportunity for user based approaches to add to the quality and value of future outdoor spaces (Figure 2).

Before the turn of the century, the relationship between physical comfort and meteorological conditions was already considered an important factor. It was recognised that such approaches could potentially enable the ensemble of physically comfortable weather conditions (Olgyay 1963; Höppe 1999). Issues such as sunlight and temperature were considerably debated by authors who expressed the significance of daylight, and the implementation of attenuation measures in circumstances of overexposure (Whyte 1980; Marcus and Francis 1990). Moreover, the importance of wind patterns upon local conditions was also established in studies conducted by (Whyte 1980; Arens 1981; Gehl 1987).

As a result, and when assessing the existing structure of the “Place Diagram,” if existing public space precedents were used to build the four existing criteria, then this raises the question of – how can new lessons be learnt when user-based adaptation efforts that combine urban climatology and urban design are still in their early stages?

Methods

In order to facilitate such guidelines, the breadth between theory and practice needs to be diminished in order to inform the better design and maintenance of public spaces in an era
of prospective climate change (Matos Silva and Costa 2016). As a result, this conjures the challenge of applying scientific information into readily available design guidance within the real-world process of public space design. It is here, within the user-based spectrum of adaptation to climate change, where microclimatic phenomena such as air temperature, radiation, humidity and wind patterns adjoin the important consideration of both the usage and longevity of public space. Considering the broad nature and the existing criteria of the “Place Diagram,” an alteration is thus proposed in Figure 3.

Figure 3 demonstrates how the existing structure of the PPS’s diagram can incorporate the increasing need to consider the possible impacts brought on by climate change. Given the “questions to consider on comfort & image” by the PPS, the only question that relates specifically to that of pedestrian comfort refers to the issue of safety and choice between sitting in areas in the sun or shade. In addition, since safety is directed at the presence of on-site security personnel, it falls short in considering how a space can transpose a sense of safety with regards to climatic hazards. As a result, it is here argued that there is an
opportunity to raise new questions that specifically consider pedestrian comfort. Naturally, such questions require new qualitative and quantitative assessments in order to correctly assess comfort levels.

In order to approach these assessments, this article uses what Katzschner (2006) determines as a “research for design” approach. This methodology focuses upon improving urban design guidelines by reviewing existing theoretical and empirical research with regards to how pedestrian comfort levels can be addressed through public space design. In addressing and incorporating these questions into a generic tool such as the one used by the PPS, this “research for design” is approached through a twofold progression method.

Firstly, and in order to overcome the lack of existing knowledge within the scientific community, the authors associate theories of psychological adaptation with that of thermal preference. The outcome of this cross-examination is a three-step approach that endeavours to aid urban designers to better comprehend qualitative criteria through a design orientated approach. Subsequently, and based on the six determined socio-psychological criteria, the three step approach is compared to eight existing empirical studies that examine thermal adaptability and psychological preference in outdoor urban spaces.

Secondly, and once the three-step approach is established, the quantitative aspects are investigated in order to determine how urban design can improve the identified “built environment layer.” This stage concentrates upon establishing the quantifiable criteria that directly influence the qualitative attributes of thermal comfort. Also summing up to six criteria, each is assessed against empirical and theoretical studies that all suggest their prevalence in improving the qualities of contemporary urban outdoor spaces. To conclude, these six quantitative criteria are extrapolated into three tiers of attributes which enable the inspection of the exact values/measurements that can be registered through site visits or computer simulations.

**Establishing qualitative criteria**

When considering qualitative criteria, it is worth noting that most (if not all) enter the psychological and sociological perception of man to his surroundings. Nevertheless, there is a considerable lack of knowledge on how to approach such a subjective area of study, and a limited amount of research has been carried out within the scope of urban design.

The concept of thermal comfort, or thermal acceptability, is crucial in urban design as it establishes the boundaries of ideal climatic conditions that should be achieved. For example, this may establish lower and upper temperature limits, maximum wind patterns and exposure to a certain level of solar radiation. As expected, and when considering local risk factors, such considerations of acceptability must always be context sensitive (Olgyay 1963; Matzarakis and Amelung 2008).

In the scope of thermal comfort in public space design, this may involve all of the processes which people go through to improve the fit between the environment and their preferential requirements. To grasp this intricate relationship, Nikolopoulou and Steemers (2003) suggest that there are six psychological factors: (1) naturalness; (2) expectations; (3) past experience; (4) time of exposure; (5) perceived control; and, (6) environmental stimulation. As these are attributes that enter the “intangible” sphere, the quantification of each parameter is complex. People perceive the environment differently, and psycho-sociological factors have a heavy influence upon the thermal perception of a space. In addition, the same
respective person can have different reactions to the encircling climate during different periods of their lives. In order to analyse such factors in design terms, one can address the study conducted by Erell, Pearlmutter, and Williamson (2011) who established three sets of potential preferences which relate to the thermal environment of public spaces. These preferences are defined as the combination of factors which influence the outdoor thermal sensation of a person, namely the:

1. Climatic Environment – Relating to the direct influence of the air temperature, radiation, humidity and wind patterns
2. Built Environment – Relating to the buildings, technology, amenities by which the climate set of preferences can be addressed
3. Human Environment – Relating to a wide range of aspects referring to people’s behaviours which affect their thermal preferences, which can range from clothes selection and activity levels at a day to day level, to wider scope which can refer to the general satisfaction thresholds of a city in a specific type of climate.

**Linking psychological adaptation with thermal preference**

By cross-examining the six psychological factors with the three environments, one can get a better understanding of each factor with the built environment. Naturalness is strongly associated to the character of place, although a much debated concept, it is here depicted as locally distinctive patterns of development, landscape and use (Cowan 2005). Resultantly, this qualitative criterion is strongly attached to the built environment layer, and where the implementations of thermal attenuation measures require congruence with the rest of the site.

Past experience is strongly related to the human environment as it is a “variable” carried by pedestrians. Furthermore, and as stated by Nikolopoulou and Steemers (2003), design approaches can also influence short-term past experience. Although this would be at a larger scale, the urban fabric can offer spatial variety in the city, whereby a rich diversity of different environments/thermal stimuli can be experienced.

Perceived control is also a mixture between the human and built environmental layers, whereby such control can be introduced by the provision of opportunities through the physical adaptation of a place. In other words, this could be accomplished by pedestrians having the choice between differing microclimatic conditions, such as areas with more sun/shade (Carmona 2014), and more or less wind (Clément and Rahm 2007).

Time of exposure is a combination of all three environments, whereby the climatic environment is the continuous variable. The built environment layer enables the means to address such microclimatic phenomenon, which in turn, affects the human environment (ie time of exposure). As an example, one can refer to the Expo of 1992 in Seville, where the public realm of the Expo was divided into three different types of spaces: (1) “Passage Areas” with the prime functionality of supporting the main flow of pedestrians, with an expected “use timeframe” of below 15 min; (2) “Rest/Stay Areas” with the primary goal of offering places for resting, eating and social congregation, with an expected “use timeframe” of over 15 min; and lastly, (3) “Adjacent Areas” that were spaces of interconnectivity between the former. This theoretical division between passage, rest and adjacent areas aided thermal comfort design to be divided into medium-level, high-level and low-level thermal condition, respectively (Velazquez, Alvarez, and Guerra 1992).
Environmental stimulation is a mixture of the climatic environment and the human environment, whereby it is the pedestrian that chooses the amount of stimulation to a given microclimatic stimuli. As indicated by Gomez-Azpeitia et al. (2011), such choices can be considerably influenced by factors such as transitioning between indoor and outdoor environments.

Figure 4. Representation of different environmental layers. Source: Author’s figure.
Lastly, expectation is a factor that is associated to both the built environment and human environment, due to the relationship between a person’s preconceived anticipation, and what they actually experience in a given space. Naturally, if a person expects to have the ability to “hide” from intense sun exposure or higher temperatures, tolerance levels are decreased due to the consequential obligation to withstand such thermal stress. As a result, factors such as time of exposure can also be affected due to the built environment not providing the means to address such attenuation measures.

In order to communicate these relationships in visual terms, a hypothetical public space is presented in Figure 4. Within the figure, the climatic environment illustrates the direct sensibility to climatic phenomenon, such as the influence of vegetation upon wind speed (blue lines), the formation of shade as a result of the tree crowns/canopies (white surfaces) and the areas exposed to solar radiation (shown in darker red). The built environment illustrates all of the built form which inevitably influences the climatic environment, such as the canopies (shown in grey) and/or trees (shown in light blue). Lastly is the human environment, containing the largest amount of aspects due to its intrinsically emotive relationship with the former layers. This layer presents the opportunity to comprehend movement patterns, areas for stationary activities, past thermal history and also the different type of areas which each influence staying times as suggested by Velazquez, Alvarez, and Guerra (1992).

Taking this line of reasoning into the practical sphere of public space design, the relationship between the six psychological criteria and the three environmental layers, can be seen...
as a three step process in influencing each of these qualitative criteria through a design-orien-
tated approach (Figure 5).

As shown in Figure 5 the first psychological attributes that are affected are the amount
of time and environmental stimuli the pedestrians choose to expose themselves to within
the public space. Initially, these mental manifestations are those that are directly influenced
by microclimatic occurrences in a given outdoor space. In order words, if pedestrians are
exposed to too much thermal stress/stimuli, regardless of the built surroundings, they shall
inevitably choose to leave. At a second stage, the built environment can be seen as a means
to address pedestrian preferences in the light of the environmental stimuli. Respectively, it
is here where comfort thresholds can be addressed by improving the amount of control
pedestrians have upon personalising their susceptibility to a respective stimuli. In addition,
if this perceived control is achieved in a natural way, ie through passive or vegetative means,
then the stimuli tolerance can be increased further. Lastly, the last phase of the process is
the result of the interventions within the built environment in combination with the climatic
environment. As can be seen in the psychological factors, such as expectations, time of
exposure and perceived control, each are situated in both the second and third phases. For
this reason there is a direct impact that physical interventions and design opportunities can
have upon the perception of an outdoor space. Furthermore, environmental stimulation
and time of exposure are also part of the human environment, thus also suggesting that
these criteria can also be influenced through local intervention.

Existing empirical studies of pedestrian thermal comfort
In order to assess the validity of this three-step approach in defining qualitative criteria, the
three layers were analysed against existing empirical studies that examined pedestrian
behaviour, and thermal comfort thresholds to outdoor microclimatic stimuli. This approach
permitted the subjective processes of thermal preferences and psychological adaptation to
be categorically organised.

Table 1 shows how eight existing studies can be divided into the three environments,
whereby the: (i) first step illustrates the environmental stimulation that was assessed in each
of the studies; (ii) second considers how the built environment affected activity patterns in
light of the assessed environmental stimulation; and, (iii) third step shows how the previous
steps influenced pedestrians to behave in a certain way, enticing them to stay longer (or
not) in the space. As shown in Figure 5, the six psychological criteria are dispersed and
repeated amongst the different layers due to an intrinsic “cause-and-effect” relationship
between one another.

To date, empirical research with regards to pedestrian comfort thresholds and thermal
adaptation is still in its initial phases. As a result, it is still problematic to produce concrete
design guidelines based upon solely qualitative criteria. Nevertheless, it is here suggested
that there is sufficient knowledge to provide reflections that can aid, and syndicate, local
placemaking with climatic adaptation efforts.

Also acknowledging this lack of studies with regards to psychological response and ther-
mal comfort thresholds, Eliasson et al. (2007) identified in their research that air temperature,
wind speed and cloud index had significant impact upon pedestrian behaviour. When con-
sidering the built environment, the interviewees revealed that they had different expecta-
tions with regards to the different microclimatic environments between an urban outdoor
public space (comprising of higher temperatures and lower wind patterns), and a waterfront
Table 1. Applying the three step process in existing studies of pedestrian comfort thresholds and thermal adaptation.

| Study | Environmental Stimulation | Perceived Control | Expectations | Environmental Stimulation |
|-------|---------------------------|-------------------|--------------|---------------------------|
| (Thorsson, Honjo et al. 2007) | Pedestrians expected waterfront plazas to have increased wind speed and reduced temperature | Higher winds were expected to be more pleasant as a result of higher wind speed and lower air temperature | Waterfront plaza was considered by the pedestrians to be part of the “positive aesthetic and symbolic value” in the waterfront plaza | Naturalness | Expectations |
| (Nikolopoulou, Baker et al. 2001) | The increase of seating alone had a very small impact on pedestrian numbers in the area | As values of thermal indices increased, the number of people frequenting outdoor public spaces also increased in the summer/winter | Pedestrians desired increased environmental stimulation due to their past experience of being inside of a building | Past Experience | Expectations |
| (Katzschner 2006) | Given the possibility to choose between indoor and outdoor seating areas, pedestrians chose to sit outside in order to experience hotter temperatures | When the individuals autonomously chose to visit the square, the thermal tolerance was high. On the other hand, when obliged to visit the square (such as being obliged to cross it), the tolerance was significantly lower | Pedestrians expected the park to be more “beautiful” as a result of lower wind speeds and higher air temperature | Environmental Stimulation |
| (Lin 2009) | 99% of the pedestrians in the study that visited the space chose to stay under trees or shelters during the summer | Although appreciated during the winter period, a street with limited or no areas to sit in the shade decreased the amount of pedestrians during the summer. Moreover, the ones that did sit, sat for shorter periods. | Pedestrians avoided the square due to the expected poor thermal comfort conditions | Time of Exposure/Naturalness | Environmental Stimulation |

(Continued)
area (comprising lower temperatures and higher wind patterns). In addition, it was also perceived by the majority of the interviewees that the higher wind speeds added to the naturalness of the built environment. When assessing the human environment, both environmental stimulation and expectations played a fundamental role in constructing an overall image of the spaces. Beyond accepting both higher wind speeds and temperatures in the different locations, these stimuli led to the waterfront area being considered more “pleasant,” and urban square as more “beautiful”.

Integrated within the Rediscovering the Urban Realm and Open Spaces (RUROS) project, Katzschner (2006) investigated the use of an outdoor space located close to a small café. The study concluded that the behaviour of pedestrians was significantly dependent upon encircling microclimatic conditions, and past experience. When analysing the psychological attributes disclosed in the study, it was identified that the built environment layer had strong influence upon thermal adaptation as a result of perceived control. More concretely, the possibility of choosing between indoor or outdoor seating areas led pedestrians to choose to sit outside in higher temperatures. When considering these implications within the human environment, this resulted in higher temperatures being both accepted and pursued. These responses can be both interlinked with environmental stimulation and past experience.

Notwithstanding, it should not be assumed that merely placing seating will increase the thermal tolerance of pedestrians as shown in Zacharias, Statthopoulos, and Wu (2004). In their study, it was shown that as part of a redesign project to increase pedestrian numbers in a public space, it was not sufficient to increase the numbers of seating areas in the space. It was verified that this increase in seating facilities had to be done with an understanding of microclimatic constraints such as sun patterns and temperature variations. In cases where the seating provision was placed in the correct locations (in regards to these outdoor characteristics), the amount of pedestrians using the seats/benches increased significantly.
Within a humid subtropical climate, Lin (2009) identified that as opposed to a temperate climate, cool temperature and weak sunlight were generally desirable during the hot season. More specifically, the recognised thermal comfort threshold for an entire year lied between 21.3 and 28.5 °C_{PET}, which is significantly higher than the European threshold of 18–23 °C_{PET} (Matzarakis and Mayer 1996). Here, it was identified that the built environment played a particular role in influencing pedestrian behaviour by the provision of choice. In addition, it was identified by the study that 90% of pedestrians chose to stay in the shade of trees/shelters, which implies that given the absence of this choice; a significant amount of pedestrians would either avoid, or stay shorter periods in the outdoor space. It was also noted that although thermal indices continued to increase due to the gradual augmentation of ambient temperatures, so did the amount of pedestrian attendance in the square. Such patterns are thus associated to the human environment. In contrast, the interviewees also revealed that the pedestrians that were obliged (ie required to cross the space to reach their destination), had a much lower thermal tolerance to the existing microclimatic conditions.

On the other hand, and as identified in a study conducted by Nikolopoulou, Baker, and Steemers (2001), this lack of perceived control in the built environment layer led to a very low amount of pedestrians during the summer due to a lack of shading facilities. Notwithstanding, the human layer revealed that pedestrians nevertheless presented a higher tolerance to environmental stimuli, particularly when they had recently exited the interior of a building.

In the study conducted by Thorsson et al. (2007), and similar to the first study by Eliasson et al. (2007), two types of Japanese public spaces were compared to one another in terms of pedestrian behaviour and thermal adaptation. The first public space was a square that had no trees, and very little shade during midday. The second was a park that contained a forested area, grassed locations and a playground. Although located close to one another, pedestrian behaviour varied significantly between the two. In terms of the built environment, the limited choice of shaded areas immediately influenced the pedestrians to not seek any comfortable conditions in the square, and led pedestrians to use the square only to undertake short activities, such as smoking, making a phone call or commuting through the square. On the other hand, the built environment of the park led pedestrians to partake in considerably longer activities such as “relaxing,” “exercising” and “eating lunch.” Furthermore, and dissimilarly, it was identified that 80% of the visitors pursued natural means of shade when ambient temperatures surpassed 20 °C (ie through sitting beneath a tree). This perceived control was also communicated into the human environment, whereby the park was generally perceived as an outdoor location that allowed greater adjustment of thermal conditions.

A similar reaction in both the built and human environments can be found in the study conducted by Thorsson, Lindqvist, and Lindqvist (2004), who also investigated the behaviour patterns of pedestrians in an urban park in Gothenburg, Sweden. Their survey revealed that pedestrians also wished to visit a green site in order to expose themselves to the sun, yet when temperatures became too high, they had the possibility to choose to move to a natural shade beneath a tree crown. As a result, and within the human environment, the interviewees also revealed that: (i) they perceived the park as location that offered a wide variety of microclimates; and (ii) they “felt better” or “much better” when visiting the park.

Finally, and also inserted within the RUROS project, the study conducted by Nikolopoulou (2007) also revealed the significance of perceived control in the built environment in
influencing the conduct of pedestrians. Given the choice, pedestrians also revealed their preference for shaded areas when temperatures increased, and thus shaded areas became busier. Nonetheless, it was still noted that during the summer period, and particularly during early summer afternoons, pedestrians perceived the space to still be too hot. This perception changed significantly, in the summer evenings where pedestrians were found to exit indoor environments to experience a cooler outdoor microclimate.

In the light of these studies, when considering the qualitative behavioural aspects of pedestrians, approaching outdoor comfort thresholds can be complex. Yet, this should not invalidate their applicability as potential tools in aiding public space design, and their improved integration with the urban climate. The cross-examination of the three layers with existing empirical studies enables a simplification of the complex relationship between climatic dynamics, built form and that of human perception.

While referring to the built environment layer, two psychological aspects were the most common in influencing pedestrian behaviour in the light of climatic stimuli. The first was perceived control, which allowed pedestrians to personify their stay within a respective space. Such personification ranged from being able to choose where to sit, to choosing whether to be in the shade or sun. As a result, this reinforced the existence of different climatic alternatives within public spaces.

As a result of addressing this psychological characteristic, the time of exposure can also be increased as evidenced by Nikolopoulou and Steemers (2003). Their study illustrated that spaces which offered these types of choices witnessed an average pedestrian staying time of 50 min, opposed to 16 min when no choices were made available. In addition, it is clear from the empirical studies that when the environments were considered natural, thermal comfort thresholds were also increased. This was particularly visible in cases which in some way integrated some type of natural feature, ie such as trees and water bodies (Thorsson, Lindqvist, and Lindqvist 2004; Eliasson et al. 2007; Thorsson et al. 2007; Lin 2009). In addition, expectations also played a significant role both before and during the pedestrians visit to the sites. In empirical terms, pedestrians that visited the spaces expected to have the ability to regulate their thermal thresholds either through moving to the shade, standing in a windier location during the summer or sitting in the sun during the winter (Nikolopoulou, Baker, and Steemers 2001; Eliasson et al. 2007).

When reflecting upon the human layer, the amount of desired environmental stimulation was very variable in all of the case studies. More specifically, every case shown in Table 1 salient that pedestrians adapt to their surroundings, and accept conditions that would appear to lie outside their physiological comfort zone (PCZ). In turn, this indicates that people are comfortable in a wide range of environments as they respond to diverse situations which lead them to have higher thermal comfort thresholds. This increased lenience is what is termed as “the adaptive approach” (Humphreys, Nicol, and Raja 2007; Erell, Pearlmutter, and Williamson 2011), which suggests that although laboratory investigations may indicate “typical” or “expected” comfort zones, this does not mean that such thresholds cannot be surpassed in the light of other factors. Furthermore, and as shown in Table 1, existing empirical evidence has demonstrated that pedestrians also choose to surpass their expected comfort zones. In addition to these examples, one can also refer back to the studies carried out in New Yorks’ public spaces which showed that the days that brought out the peak crowds on plazas were not sparkling sunny days with temperatures in the [low 20°Cs] (...) it was the hot, muggy days, sunny or overcast, the kind
that could be expected to make people want to stay inside and be air conditioned, when you [would] find the peak numbers outside. (Whyte 1980, 44)

For these reasons, it is here suggested that multi-agent software programs such as “BOTworld” (Bruse 2007) must be used with caution, as they often assume that pedestrians only accept environmental stimulation when it is within their thermal comfort thresholds. Therefore, this raises the need to formulate better “predicting tools” that better explain the relationship between outdoor climatic stimuli and the subsequent reaction of pedestrians (Givoni et al. 2003; Chen and Ng 2012).

In order to move towards such tools, it is fundamental to consider that pedestrians are organisms which avert climatic monotony, even if this implies that such desired fluctuations may expose them to environmental stimulation that surpass their PCZ. From the empirical studies, it is possible to establish that a pedestrian that desires to visit an outdoor space will also expect to personify their visit in numerous ways, including adjusting their thermal regulatory system. For this reason, regardless of their decision for more or less environmental stimulation, the crucial aspect in prolonging their stay in the outdoor space is to consider their expectations. As to be expected, and due to being an idiosyncrasy correlated to the human psyche, it would be naive to assume that one could acknowledge every expectation that pedestrians may have when visiting the space. However, this obscurity should not be mistaken with the ability to consider general microclimatic implications, and how they affect urban outdoor spaces. As a result, it is here where space personification becomes essential through the introduction of choice in public space design. When introducing such means to increase perceived control, urban designers must thus consider design solutions that substance such fluctuations of environmental exposure. When considering this in empirical terms, and as shown in Zacharias, Stathopoulos, and Wu (2004), in these circumstances, it is here where quality over quantity may lead to dramatic increases in pedestrian numbers in urban outdoor spaces.

Although all the psychological factors are indeed intrinsically qualitative, it is nonetheless argued that they can be influenced through public space design. It is here where design can be approached in a three step approach that understands the microclimatic constraints, provides physical responses and lastly influences the comfort of pedestrians. However, in order to successfully insert such interventions within the built environment, or “Human Made Phase,” a quantitative approach is also required and thus extrapolated in the ensuing section.

Establishing quantitative criteria

Moving from qualitative aspects, pedestrian comfort is also attained through quantitative criteria in order to introduce measures that can improve comfort levels. In this scope, different measurable data can raise deliberations into the aspects that need to be considered, and/or modified, when considering pedestrian comfort. Figure 6 demonstrates the measurable data, and their specific characteristics which can be attained by field studies and/or research.

Local microclimatic data

The first data group is the “Local Microclimatic Data,” which presents the local meteorological characteristics of the site. The measurements of the characteristics can be made through a mixture of 3D modulation, and direct measurement through climatological equipment.
| Measurable Data                          | Specific Characteristics                                                                 |
|----------------------------------------|------------------------------------------------------------------------------------------|
| **Local Microclimatic Data**           | ![Wind](image1), ![Radiation](image2), ![Humidity](image3), ![Ambient/Surface Temp.](image4) |
| **Urban Morphology**                   | ![High H/W](image5), ![Med. H/W](image6), ![Low H/W](image7), ![Canyon Orientation](image8) |
| **Greenery & Amenities**               | ![Canopies](image9), ![Vegetation](image10), ![Water Feature](image11), ![Materiality](image12) |
| **Availability of Choice**             | ![Local Scale](image13), ![Micro Scale](image14), ![Radiation Variation](image15)          |
| **Surrounding Context**                | ![Regional Variation Points](image16)                                                    |
| **Future Climatic Risk**               | ![Temperature Increases](image17), ![Heat Waves](image18), ![UHI Effects](image19)       |

Division into the principal microclimatic characteristics that directly influence thermal comfort.

Division of different types of canyon compositions and composition that influence their individual microclimatic/thermal constraints.

Division of the principal local interventions that can directly influence thermal comfort in a respective space without H/W modification.

Division of the two principal characteristics that affect/induce choice making and the personification of thermal stimulation/comfort.

At a larger scale, surrounding context provides further information that can influence the expectations and desired stimuli of pedestrians in a specific public space.

Division of phenomenon established by future projections until the end of the century that will affect and intensify existing microclimatic constraints.

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**Figure 6.** Specific characteristics of the quantitative criteria for pedestrian comfort. Source: Author’s figure.
The influence of wind on pedestrian comfort can be seen as twofold: (1) decreasing a given surface temperature through convective heat transfer; and, (2) the effect it can have upon the mechanical functioning of the human body at higher speeds (Esch 2015). The effect of solar radiation incoming from the sun (ie short wave) upon pedestrians and surfaces is likely to be the principal deterrent in influencing thermal comfort in a respective urban space (Erell, Pearlmutter, and Williamson 2011). Relative humidity is the relationship between actual vapour pressure and saturated vapour pressure, this intrinsic balance can either decrease ambient temperature or exacerbate ambient moisture levels, and consequently decrease comfort levels (Nouri 2015). Lastly, ambient and surface temperatures also play a significant role, and furthermore, have an intrinsic “cause and effect relationship” with one another (Georgakis and Santamouris 2006; Santamouris 2013).

It should be noted that in order to accurately measure “Local Microclimatic Data” in terms of establishing a wholesome understanding of pedestrian comfort, the human energy balance must be considered. It is here where the Physiologically Equivalent Temperature (PET) can provide significant aid to local designers through the application of the software platforms such as the “Rayman” model (Matzarakis 2000). This platform permits the actual microclimate to be evaluated in terms of its influence upon the human biometeorological system, thus leading to an understanding of pedestrian comfort given a set of meteorological stimuli in a specific urban locus.

**Urban morphology**
When considering urban morphology, and despite the heterogeneity of a street (urban canyon henceforth), when considering the fabric of buildings and open spaces in quantifiable terms, the variations of canyons can produce significant modifications to the microclimate. As a result, this raises the need to consider the aspect ratio, or Height-to-Width Ratio (H/W), which describes the sectional proportions of the urban canyon. More specifically, it represents the ratio between the average height of adjacent building façades and the average width of the space. One of the biggest dissimilarities between high, medium and low H/W ratios is the quantifiable exposure to the sky, which is termed as the sky view factor (SVF). The higher the SVF, the more amount of sky is seen in a given area/surface, which directly correlates to the higher exposure to solar radiation. Nonetheless, orientation is also a fundamental quantitative factor both in terms solar radiation and wind exposure. For example, if the orientation of a high H/W canyon is perpendicular to predominant wind flow, then the wind tunnel effect will be replaced with the more attenuated occurrences of wind eddies permeating from the top of the street. Furthermore, orientation has a dramatic influence upon solar exposure and shadow behaviour due to the dominant positioning of the sun in the sky.

**Greenery & amenities**
As the climate change agenda continually gains new weight, local designers are increasingly exploring the capacity of “Greenery and Amenities“ to address pedestrian thermal comfort. In recent decades, the dissemination of new knowledge has thus strengthened the contributions “Greenery and Amenities” can provide to thermal comfort in public space design. In this light, four different types of options shall be considered: shade canopies, vegetation, water and vapour systems and materiality (Nouri 2015).
In the case of shade canopies, such knowledge has aided the strategic placement of structures that can also attenuate solar radiation levels. Yet, such decisions should be accompanied by the local and annual understanding of public space's: (1) pattern of solar radiation exposure; (2) shadows that are cast from on-site elements (ie such as vegetation and amenities); (3) shadows that are cast from off-site elements (ie such as contiguous structures and buildings); and, (4) encircling wind patterns.

So far, a substantial amount of research has revealed that urban vegetation may be employed as a method to considerably reduce urban temperatures. Nevertheless, within the scope of public space design, there is very limited knowhow at the design guideline level with regards to microclimatic interaction between outdoor spaces and vegetation. To successfully assess this interaction in more detail, it is here suggested that two focal elements need to be understood in the application and measurement of trees in attenuating ambient temperatures and/or reducing solar radiation. The first factor is discussed by Ochoa de la Torre (1999), who analysed the potentiality of using the effects of specific vegetative configurations, namely: individual/linear plantation (LP), group plantation (GP), surface plantation (SP) and pergolas (PG). The second quantitative factor is the species of the vegetation, which accounts for important characteristics such as tree size, growth dimensions, crown density, biomass and foliation periods. Studies undertaken by (McPherson 1984; Almeida 2006) examined 47 tree species and were cross-examined to verify that the transmissivity of plants varied considerably as a result of twig/leaf density and foliage development.

With regards to the third characteristic in this group, the presence of water and misting systems is increasingly being used as a means to improve climatic conditions in outdoor spaces (Nunes et al. 2013). The wholesome effectiveness of evaporative cooling techniques is one that is contingent upon a variety of quantitative factors. Namely, and in order to effectively lower ambient temperature without imperilling acceptable humidity levels, the correct water pressure, nozzle type and functional period must be established. When relative humidity (RH) is too high, the rate of evaporative cooling of sweat is reduced, thus impeding the body’s natural process of thermoregulation. On the other side of the spectrum, although measures that enable surface wetting (such as a fountain, or a another surface that contains water) are more simplistic in their applicative nature, relative humidity levels should still be considered in order not to exacerbate ambient moisture, and thus diminishing pedestrian comfort levels.

Through the design of the public realm, the use of “cool materials,” which contain both high reflectivity and thermal emissivity values, can lead to the decrease of surface/ambient temperatures and thus significantly improve the thermal comfort in public spaces (Santamouris et al. 2012). Thus, and undertaking a quantitative approach, such improvements can be made through the replacement of conventional paving surfaces that present higher surface temperatures. Such replacements aim to introduce materials with higher solar reflectivity (ie albedo) and emissivity. In quantitative terms, and within the considerable range of projects that have already introduced such materials to diminish both ambient temperatures and disperse effects of UHI; reductions of up to 5 K in ambient temperature and 11 K in surface temperature were achieved (Santamouris 2013; Nouri 2015).

On this note, it is worth concluding the success of “Greenery and Amenities” is dependent on the combination of the different measures. Respectively, although each of the specific characteristics should be understood differently in terms of addressing pedestrian comfort, their crucial efficacy lies in their applicative permutation with one another.
### Availability of choice

Availability of choice is the most subjective of the quantitative factors because the facilitation of choice is resultant upon a combination of elements. The first characteristic in this data group is the presence of areas with different microclimatic conditions which result from the combination of the previously discussed climatic environment and built environment layer. In other terms, this employs designers to exploit the interplay of their proposals with the

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**Figure 7.** Comparison of existing PET and a modest projection of PET for the Mediterranean area by 2100. Source: Author’s figure + content adapted from (Höppe 1999; Matzarakis and Amelung 2008).

| Existing (i.e. CNTRL Values) | Future Projection under the IPCC’s A1F Scenario for the northern hemisphere summer season |
|-----------------------------|----------------------------------------------------------------------------------------|
| **PET (°C)**                | Thermal Perception | Grade of Physiological Stress | PET (°C) + PET (°C) | Thermal Perception | Grade of Physiological Stress |
| ≥                          |                 | Extreme Cold Stress          | 4 °C + PET (°C) = 14 °C | Slightly Cool     | Slight Cold Stress          |
| 4 °C                       | Very Cold       | Strong Cold Stress           | 8 °C + PET (°C) = 18 °C | Comfortable       | No Thermal Stress           |
| 8 °C                       | Cold            | Moderate Cold Stress         | 13 °C + PET (°C) = 23 °C | Slightly Warm     | Slight Heat Stress          |
| 13 °C                      | Slightly Cool   | Slight Cold Stress           | 18 °C + PET (°C) = 28 °C | Slightly Warm     | Slight Heat Stress          |
| 18 °C                      | Comfortable     | No Thermal Stress            | 23 °C + PET (°C) = 33 °C | Warm              | Moderate Heat Stress        |
| 23 °C                      | Slightly Warm   | Slight Heat Stress           | 29 °C + PET (°C) = 39 °C | Hot               | Strong Heat Stress          |
| 29 °C                      | Warm            | Moderate Heat Stress         | 35 °C + PET (°C) = 45 °C | Very Hot          | Extreme Heat Stress         |
| 35 °C                      | Hot             | Strong Heat Stress           | 41 °C + PET (°C) = 51 °C | Very Hot          | Extreme Heat Stress         |
| 41 °C                      | Very Hot        | Extreme Heat Stress          | < PET (°C) + PET (°C) = PET (°C) | Very Hot          | Extreme Heat Stress         |
| ≤                          |                 |                             | PET (°C) = PET (°C) = PET (°C) |                 |                             |

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microclimatic properties that “sometimes overlap, separate, regroup, densify, dilute, generating a variety of atmospheres where the users can choose and appropriate as they see fit.” (Mosbach, Rahm, and Liu 2012, 2). The second characteristic can be quantifiable by the amenities to amplify such personification behaviours by the pedestrians (Knuijt 2013; 

| Three Tiers of the Quantitative Criteria |
|------------------------------------------|
| Tier One                                  |
| Local Microclimatic Data                 | Urban Morphology | Greenery & Amenities | Availability of Choice | Surrounding Context | Future Climatic Risk |
| (A)                                      | (B)             | (C)                  | (D)                    | (E)                 | (F)                  |
| Tier Two                                  |
| (A.1) Wind                               | (B.1) High HW   | (C.1) Canopies       | (D.1) Local Climate Variation | (E.1) Regional Variation Points | (F.1) C^o + Temp. Increases |
| (A.2) Radiation                          | (B.2) Med. HW   | (C.2) Veg.           | (D.2) Radiation Variation | (E.2) UHI Effects | (F.2) UHI Effects |
| (A.3) Humidity                           | (B.3) Low HW    | (C.3) Water Ft.      | (D.3) Materiality       | (E.3) Heat Waves |
| (A.4) Amb/Surf Temp.                     | (B.4) Canyon Orient. | (C.4) Radiation Variation | (D.4) Radiation Variation | (E.4) Heat Waves |
| Tier Three                                |
| Speed                                    | Low SVF         | Coverage /Geometry  | Generation/Densification of different climatic areas based on existing microclimatic attributes |
| Direction                                 | High Plan Area Density | Construction Properties | (C.1) Species |
| Mean Rad. Temp.                          | Med. SVF        | (C.1) Planting Layout |
| Shadow Patterns                          | Med. Plan Area Density | (C.2) Evaporation Potential |
| (A.1.1)                                  | High SVF        | Evaporation Method   |
| (A.2.1)                                  | Low Plan Area Density | (C.3.1) Emissivity |
| RH%                                      | Solar Path Dom. Wind Patterns | (C.4.1) Reflectivity |
| (A.3.1)                                  |                  |                      |
| PET                                      |                  |                      |
| C^o                                      |                  |                      |
| (A.4.1)                                  |                  |                      |

Figure 8. Three tiers of the quantitative criteria. Source: Author’s figure.
Carmona (2014). In turn, this narrates to the strategic placement of each of the interventions disclosed in the “Greenery and Amenities” categories.

**Surrounding context**

At a larger scale, the surrounding context can provide very useful quantitative data which can aid the addressing of pedestrian comfort within a relevant public space. In addition, this characteristic can be broken down further into sub-characteristics such as proximity to green spaces, the surrounding permeability and/or H/W and the intrinsic relationship with surrounding interior spaces. In general terms, context can have an influence upon many of the qualitative factors of pedestrian comfort, and can significantly affect the amount of time pedestrians choose to spend on site. Moreover, and now specifying upon that of microclimatic implications, the surrounding context can also provide information on larger scale meteorological behaviour, which may salient obstacles/opportunities for the public space (Alcoforado and Andrade 2006).

**Future climatic risk**

Future climatic projections provide a basis of quantifiable data, which in this scope, pertains to the projected increases in temperature, augmented effects of UHI and amplified heat-waves. Nonetheless, there shall always be a certain amount of uncertainty associated to possible future climate change due to the presence of unpredictable factors which can considerably influence forthcoming climatological trends. Acknowledging this uncertainty, and in order to approach possible climatic outcomes until the end of the century, a range of scenarios were developed by the Intergovernmental Panel on Climate Change (IPCC). This global scientific institution undertook an exploration into the possible changes in socio-economic conditions that would thus lead to a range of possible scenarios, known as the Special Report of Emission Scenarios (SRES) (IPCC 2000). Resultant of these scenarios, greenhouse gas (GHG) emissions and atmospheric concentrations of greenhouse gases could be estimated, thus allowing the comprehension of the reactions within the global climate system. Among the four main SRES, the A1F represents the case with the fastest and most dramatic effects upon climate change predictions, while the B1A and B2A scenarios represent more attenuated levels of climatic variation until the end of the century. For this reason, the A1F scenario, one which portrays a “world of fast economic development and rapid introductions of innovative efficient technologies” (IPCC 2000), can be used to consider the most pessimistic future situation through a “What if?” approach (Costa 2011; Costa et al. 2014).

In this scenario, many parts of the world, including the Mediterranean, show increases in PET by at least 10 °C (some areas Mediterranean witness an increase of up to 15 °C). These quantitative conclusions were disseminated by Matzarakis and Amelung (2008) who utilised GCM’s and emission scenarios for the period 2071–2100 in comparison to the normal climate period, ie 1961–1990 (CNTRL). These quantitative outputs are of quintessential significance, as they demonstrate that the expected changes in air temperature, for the same period, are acutely lower (ie of around 4 °C).

In Figure 7, a combination of sources was used to demonstrate how existing thermal perception and physiological stress can be quantifiably influenced by the end of the century. PET$_{(x)}$ represents existing levels and the associated thresholds of pedestrian thermal perception, and the resulting physiological stress. It is worth noting here that PET$_{(x)}$ levels are adapted to the Mediterranean context, and thus do not require modification within most of the southern European region.
Based on an increase of 10 °C in PET, future projected PET (ie PET\(_{(y)}\)) is presented, and subsequently cross-referenced to that of thermal perception and physiological stress. As can be seen, this modification leads to a considerable increase in physiological strain for humans based on PET\(_{(x)}\) thresholds. Solemnly, this implies that where a “comfortable” threshold may hold today at around 18 °C, this would translate into a “comfortable” threshold of located at around 4 °C by the end of the century. It is worth reinforcing that this is under a modest scenario.

As such, projections of “solely” increases in temperature provide considerably less precise data in the local and user based scope of public space design, thus enforcing the need to consider quantitative human bioclimatic indices such as PET.

In addition, considering UHI during the discourse of the twenty-first century, it is recognised within the scientific community that global climate change can interact with the future enveloping of the built environment, and shall inevitably affect urban bioclimates (Wagner 1994). To date, numerous studies have shown that UHI effects have increased during the twentieth century (Brázdil and Budiková 1999; Philandras, Metaxas, and Nastos 1999). The former study identified a quantifiable annual increase of 0.01 °C in the UHI effect during the summer until the 1960s, which later came to stagnate. Nevertheless, and as indicated by Oke (1976), the magnitude of UHI growth are limited due to new urban structures requiring the demolishing of others once a certain level of urban development is attained. This being said, designers should have such quantitative values in consideration as they are sufficient to intensify already high temperatures in urban regions.

Lastly, and following the AR4 of the IPCC, it is established that within the twenty-first century, the occurrence of both hot extremes and heatwaves are “very likely” (IPCC 2007). Furthermore, it is also suggested by the IPCC in its AR5 that the influence of prospective climate change upon heatwaves shall be more significant than the impact upon global average temperatures (IPCC 2013). In addition, quantitative studies have shown: (1) an increase in the duration, frequency and intensity of heatwaves observed in the Mediterranean region (Kuglitsch et al. 2010); and, (2) a doubling in the length of European heatwaves between 1880 and 2005 (Della-Marta et al. 2007). Respectively, and in conjunction with increased temperatures, and UHI patterns, the effects of heatwaves must also be considered when addressing pedestrian comfort levels through contemporary public space design.

In summary, each of the six quantitative factors can be assessed and/or measured through different means. Furthermore, and as shown in Figure 8, each of the factors is presented within a three tier system of values which directly, or indirectly, influence pedestrian comfort, where: (1) Tier One illustrates the six factors (ie A–F.#.#); (2) Tier Two shows the specific characteristics of each of the factors (ie #.1–4.#); and lastly, (3) Tier Three demonstrates how most of the characteristics can be broken down further into exact measurable quantities/extents (ie #.#.1–3).

**Results and discussion**

Based upon the integration of new qualitative and quantitative criteria when addressing comfort levels in public spaces, this article suggests that existing approaches such as the “Place Diagram” can, and should, be modified in the light of the opportunities presented by climatic adaptation. Given the projected impacts of climate change, the importance of developing alleviation recommendations at design guideline level shall inevitably escalate for placemaking (Costa 2013; Nouri and Matos Silva 2013). For this reason, it is argued that the
attribute of “Comfort” in a world of possible climate change shall become a continually pressing factor for designers and decision makers. This thus implies that facilitating the provision of design guidance in generic public space evaluation models must consider such obstacles when evaluating the long term “success” of a public space. Invariably, although a present public space may demonstrate “successful” characteristics, without addressing pedestrian comfort, such characteristics in the future may no longer be sufficient in sustaining public life and affluence.

As shown in Figure 9, the objective of restructuring is not to compete with the other factors as established by the PPS. Instead, the goal is to complete a generic approach in identifying the wholesome “success” of a respective public space in a century that can witness continually growing climatic threats.

Figure 9. Restructured Place Diagram. Source: Author’s figure + content adapted from (PPS 2003b).
Conclusion

This article argues that approaches such as the “Place Diagram” need to be modified in order to consider the ever-growing importance of pedestrian comfort given events of increased temperatures, heat waves and UHI effects. This by no means advocates the invalidation of the previous criteria established by experts in the field. Instead, it is here disclosed how user-based approaches to microclimates and prospective climate change can add to the constituents of a “successful” place in order to certify its future use and socio-economic prosperity. As a result, the triangulation between climate change, urban design and user-based approaches to adaptation can lead to the fortification of design guidelines in light of local risk factors. Although a lot of the knowledge is not new, there is, however, an acute lack of knowledge between scientific expertise and its respectful application in design terms. In this respective subject area, this pertains to designers often lacking the indicators to: (1) address existing microclimatic implications in public space design; and more prominently, (2) prepare for the invigoration of these respective insinuations as a result of potential climate change.

As a result, and within the generic scope of the “Place Diagram” new quantitative and qualitative factors were introduced to stimulate new important interrogations with regards to placemaking and that of pedestrian comfort. Through the cross-examination of theories in order to approach intangible factors, and the overview of measurable data, knowledge regarding outdoor thermal comfort can be more efficiently assimilated with climate responsive public space design in an eventful twenty-first century.

Acknowledgements

This article would like extend the author’s gratitude to: (i) the Portuguese Foundation for Science and Technology for the doctoral grant with the following reference code (SFRH/BD/94521/2013); (ii) Centro de Investigação em Arquitetura, Urbanismo e Design (CIAUD) - Faculdade de Arquitetura, Universidade de Lisboa (FA/ULisboa).

Disclosure statement

No potential conflict of interest was reported by the authors.

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