178: Sustainable Design For Retail Buildings

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Abstract

This paper aims to analyze different contemporary retail environments, focusing the attention to suburban shopping centres, whereby often the so called 'American model' was widely copied throughout the world. The result of this application is often artificially lit boxes with constant thermal environments throughout the year, which does not work towards the achievement of both comfort and energy efficiency.

The study considers different examples of retail spaces, vernacular and contemporary, from open air markets to big suburban malls, and compares them against their permeability to the environment. To back up the analysis, measurements and daylight simulations were undertaken, while observations led to a conclusion: different retail typologies generate different comfort expectations in the customers, according to the diverse openness to environmental stimuli.

Retail centres need to be redefined to become more energy efficient and have the potential to become even Zero Energy Buildings.

The paper analyzes possibilities for adaptive comfort in retail environments, as the perception of comfort in transient situations (e.g. car park to building, atrium to shops) is affected by the degree of abruptness of the thermal transition.

Finally the work presents a design proposal for the Carosello Shopping Mall in Milan, where the proposed solution is a structure that provides intermediate thermal steps in the journey from the car to the shops. The proposal challenges the current design for such retail spaces and can be applicable to other schemes.

Keywords: retail centres, mall, adaptive comfort, thermal transients, thermal comfort, daylighting

1. Introduction

Shopping malls are often the synonym of consumption and misuse; they represent the architectural translation of one aspect of modern life, consumerism, but rarely do they succeed in integrating the very contemporary environmental awareness. Particularly air conditioning systems and extensive use of artificial light often fail to match real consumers' needs for comfort.

Suburban outlets are growing in the outskirts of the European cities, often mining the local small commercial activities. Moreover they require, in the very first stage, energy to be reached, as they are located near motorways.

At the same time in the city centres, retail complexes grow bigger and bigger and become non-places (Auge', 1999) where people are willing to spend longer time than before.

Although it is now accepted that the community gathers in these "boxes" and social life takes place, the environmental quality of most of the retail centres is very poor; the research into vernacular architecture teaches us that social life has always happened next to commercial activities, but in better environments such as markets and arcades.

The UK adopted the "American model" for retail design, so suburban shopping centres are often artificially lit boxes, with uniform thermal environments throughout the year regardless of climatic conditions. High internal temperatures in winter and low in summer are not only working against an efficient use of energy, but generate thermal shocks instead of providing opportunity for the human body to adapt.

On the other hand, some 'environmental injection' has been made in some recent retail buildings, where one can hear birds singing in the loud speakers and can eat in the "Piazza", the artificially lit food court, but still dreams of a weekend in the Riviera.

Nowadays artificial lighting is the biggest figure in terms of energy consumption for non residential buildings. A proper use of natural light can instead provide visual comfort whilst allowing a better quality of light.

As for ventilation and air control, the uniform environments that shopping malls create throughout the year often do not correspond to the requirements of thermal comfort. Air curtains located in the entrances, for example, work as a thermal shock instead of driving the user towards adaptive comfort.

A deeper research into real consumer's needs for thermal and visual comfort is another objective of this work; the observation of built examples, from the vernacular to the contemporary, is here presented and, in some cases, integrated with field measurements and simulations.

Thermal transients and adaptive comfort are the main theories that influenced this work: the literature research, the observations, the measurements and the use of software tools for simulations were all used to define the environmental variables and make hypotheses on the psychological ones. The result is a design of a structure, the "buffer zone", which expresses the requirements for adaptive comfort with a form that drives the user through a series of intermediate environmental steps.

2. The permeability subdivision

The following spectrum of case studies was classified in terms of permeability to the environments, i.e. air and daylighting.

2.1 Open air markets and porticos

Open-air markets represent the most traditional commercial area since ancient civilizations. This typology is completely subject to weather conditions, i.e. air temperature, solar radiation (though it can damage the exposed items), wind and relative humidity.

Although markets are perceived as outdoor environments, their architectural space is however precisely defined. Features like smells (e.g. incense), noises and the above described environmental variables, make open air markets vibrant retail spaces.

2.2 Porticos

Porticos are historically the first attempt to create a shelter from the environments, rain in particular. The shelter is also affecting daylight as in most circumstances direct solar radiation is not able to reach the inner side of the shop front, protecting the items, and creating the possibility for shop windows to be brighter, emphasizing therefore the merchandized goods.

Some of these features have been recreated also in modern enclosed shopping environments.

2.3 Arcades

Shopping arcades are an historical and architectural testimony of the late 19th century industrial era. Located mostly in the centre of the city, arcades are transitional spaces where the shopping activity takes place during the journey. In this scheme the level of permeability to light and air is functional to the percentage of glazed surface on the roof and the width/height ratio of the arcade’s section. Glazed surfaces range from glass cubes, creating a uniform day-lit roof, to glass connected to the steel structure.

Shops face the corridor and represent the threshold between private and public space; they normally have an independent conditioning system and regulate separately the level of lighting in the shop windows.

These spaces can be very bright and shop windows can suffer from glare as they’re directly exposed to solar radiation.

Galleria Vittorio Emanuele in Milan is one of the most famous examples of urban arcades; its monumental proportions, luxury decorations and high-end shops, have made it famous all over the world.

Figure 1 - Galleria Vittorio Emanuele , Milan

The north-south distribution of the thoroughfare and the wide glazed surface of the roof make it possible for solar radiation to touch west and east shop façades. Despite the presence of glare in summer and the lack of heating gains from the sun in winter, the customer’s satisfaction in the Galleria Vittorio Emanuele is rather high. Not only does the Galleria stay cool on warm summer days because of the thermal mass, but in winter days the clothing level and the transient activity are enough to match customers’ comfort.

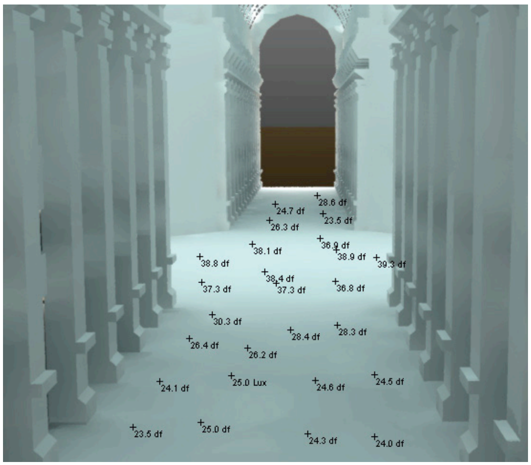


Figure 2 - Radiance simulation of Galleria Vittorio Emanuele, Milan

2.4 Bluewater Shopping Mall, UK.

Engineered by the British practice Battle Mc Carthy, Bluewater shopping centre was to put a milestone in sustainable design for retail centres: the use of natural ventilation, the landscaping of the surroundings and the overall design based on sensorial stimuli were the main inspirational criteria.

Figure 3 – Bluewater Shopping Centre

In order to understand the light relationship between mall space and shop fronts, illuminance measurements were taken with a luxometer in different parts of the building. Outer condition: overcast day (6400 to 6100 lux during measurements). Data were collected in the middle of the corridor on the ground floor and the upper corridor in order to calculate the daylight factor. Other measurements were taken next to several shopping windows in order to see the range of illuminance of different shop fronts.
When not shaded by the upper floor the ground floor reached values of illuminance of 2200 lux (Fig. 3 b, daylight factor =34).

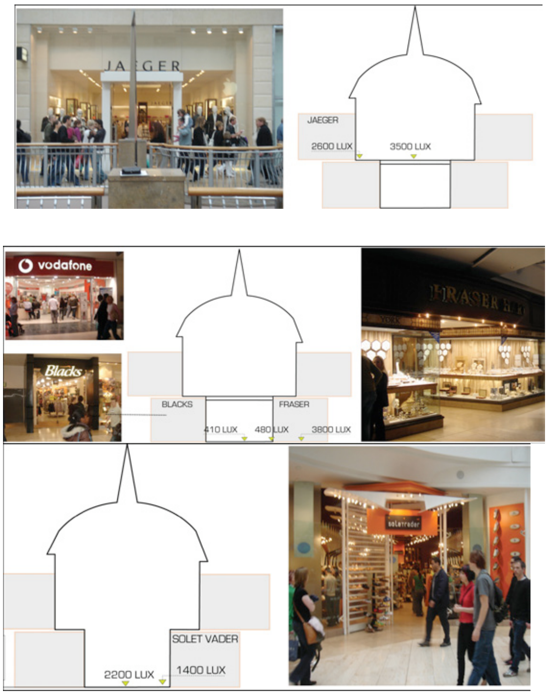


Figure 4 - a b c Shop front typologies - Illuminance measurements

When the slab of the first floor crosses the corridor those levels drop at 410 lux (DF = 6.4); in the upper floor values of 3500 lux were reached which means a daylight factor of about 50. Different shop fronts interact differently with the daylight (Fig. 4 a) provided in the main corridor and create accent lighting respectively to the items (Fig. 4 c right) or to the brand (Fig. 4 c left).
In Bluewater shopping mall the generous roof windows generate high values of illuminance, far above the minimum requirements of 300 lux prescribed by the Cibse Guide; this is not always an advantage: such amount of daylight is not necessarily needed by the customers; moreover shop fronts require more artificial light (i.e. more energy) in order to be emphasized.

Figure 5 – The roof lights

As for air temperature and the collected measurements were surprisingly constant throughout the mall and varied of ΔT=0.9 - 1 ºC from the center of the corridor to the side of it, proving the cooling contribution of the singular air conditioning systems of the shops. Conclusions:

- Cooling loads come from the shops.
- Air conditioning in the shops varies from 21 to 23.7 ºC.
- The inner temperature varies about 1 ºC from lower to upper level of shops.
- The measured temperatures are above the target values conceived for spring.

2.5 The 'American model'

Figure 6 – A typical shopping mall in the US

Several case studies of more traditional shopping malls were analyzed, with particular reference to building performance in relation to exposed area and opaque / transparent surfaces rate.

2.6 Conclusions

The investigation of the case studies brought to the following conclusions for commercial spaces:

- Different retail typologies generate different levels of climatic expectations in the customers.
- Open and permeable structures offer a wider range of stimuli, hard but not impossible to recreate indoors.
- Compact structures are better at saving energy.

- Permeability to daylight is not always a synonym of energy savings.
- The mall (corridor/distribution space) has a minor energy impact on the total consumption.
- The mall should be a zero energy space; moreover it should tackle the real energy consuming factors: artificial light in shops (especially shop windows) and thermal exchange to the outer conditions.

3. The case study, Carosello Shopping Mall in Milan

The chosen case study for this work is the Carosello Shopping Centre located in the outskirts of Carugate, a small town near Milan. This example created the opportunity to simulate its geometry, to develop hypothesis on ventilation and comfort, to implement the previously described conclusions and eventually to freely re-interpret the design the mall space.

3.1 Occupancy gains and ventilation

As tested during the observation of the activity in Bluewater, averagely occupants:

- walk along the corridor (about 30%)
- walk slowly along the shopping windows or transversely in the corridor (50%)
- stand for more than 5 minutes next to the kiosk, or sit on a bench or stand speaking (20%).

Relative metabolic rate (source IDEA Comfort):

- Walking– on the level (3.2 Km/h) : 116 W/ m^2
- Walking slowly – on the level (less than 3.2 Km/h): about 90 W/ m^2
- Standing, relaxed – 70 W/ m^2.

The considered body surface for an adult was considered to be 1.8 m^2 . The density observed in Bluewater on a Saturday afternoon varied from 45 to 58 people during the two hours (area 200 m^2), so 0.23 to 0.29 people/ m^2, An average value of 0.26 people/ m^2 was considered.

So, for an area of 100 m2 the internal gains will be

1. 0.3 (30%) x 26 (people) x 1.8 m^2 (body area) x 116 W/m2 = 1629 W
2. 0.5 x 26 x 1.8 x 90 = 2106 W
3. 0.2 x 26 x 1.8 x 70 = 655 W

Total: 4390 W, so about 44 W/ m^2 = internal gains (for maximum occupancy level). The suggested air requirement for a shopping centre (source: Cibse Guide) is 8 l/s per person. The value, though very generous considering that it's a transitional space, is easily achieved. For example, in 100 m^2 with the ceiling at 6m of height, the volume of air will be of 600 m3. The amount of needed air for an hour will be: 26 (persons) x 8 (L*pers -1 * sec-1) * 3600 (sec) = 748,800 L= 748.8 m3. For such space: 748.8/600= 1.25 ACH will be needed. Generally speaking distribution spaces in retail centres have very high ceilings and a generous volume of air is available. If the amount of fresh air coming from the shops is then considered the situation gets even better.

A model in TAS was developed in order to compare the air temperatures achieved from high level air suppliers and low level. Such air temperature was tested at 'perception level' i.e. in a zone between 1m and 2m above the floor, and the data were calculated for air supplied at 24, 25 and 26 deg Celsius, proving that in most of the cases the air supplied with low level suppliers acts in a much more efficient to provide air temperatures within comfort ranges at perception level.

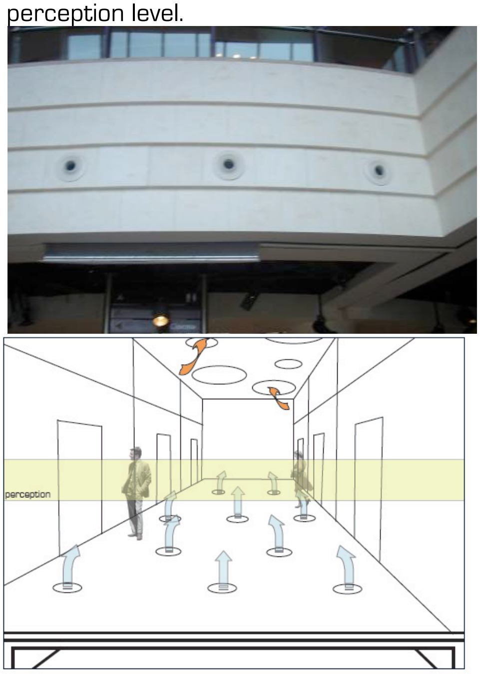


Figure 7 – a,b Schemes of ventilation with high and low level suppliers

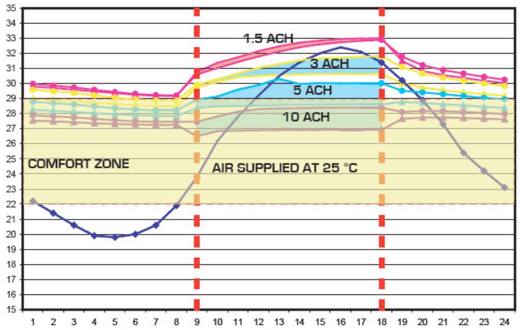


Figure 8- Parametric study: air supplied at 25C, comparison between high and low level air suppliers with different ACH

The lines with the triangles and circles represent respectively temperatures achieved with low and high level air suppliers. Red areas: high level performs better than low, blue the opposite situation.

By increasing the ACH, internal air temperatures decrease until they are in the comfort zone.

For example with 5 ACH at 25 °C (Fig. 8) and low level suppliers the temperatures are similar to those of 10 ACH with high level suppliers. This parametric study shows that a good ventilation strategy can provide comfort without extra use of energy; a further study on frequency of occurrence showed that external air temperatures can be used widely throughout the year for this climate.

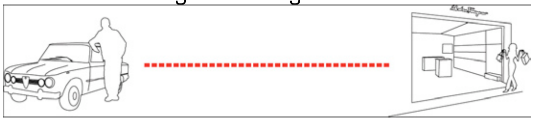
4. Design

After the observations and the conclusions from the analytical approach, a design option is here presented. The goal was to design a 'buffer space', i.e. a passive space that would create adaptive comfort opportunity for the customers and eventually bring environmental benefits to the overall building performance too. In this space, adaptation should already start from the car parking area: by going out of the car the customer has a first thermal transition and enters already in a designed space, the car park.

Therefore a buffer zone should tackle the factors compromising thermal comfort already here; its functions should be:

- mitigating the heat island generated by the asphalt surface for the outdoor space;
- creating a semi enclosed space for distribution, with various thermal transitions;
- providing permeability to natural light and natural ventilation inside the building.

This work intends to study the different comfort scenarios during the journey from the car to the mall and to give a design solution.



4.1 Minimizing the heat island in the car park

The scheme of the existing parking area was kept in order to formulate possible solutions for the existing difficulties. The car park consists of a 54.500 asphalt surface that can reach temperatures of 51-53 °C during a hot summer's day. The heat island affects:

- the walls adjacent to the car park, therefore the building performance;
- the pedestrians crossing the car park, who are subject to air and radiant temperatures and solar radiation;
- cars, that will increasingly accumulate heat and later consume more energy to cool down.

Asphalt has a solar absorption of 0.9 and releases heat very slowly. In order to mitigate the heat island the following implementations are recommended: substitution of part of the radiant surfaces with green areas and create shade in the car park. In the zones where cars park and don't need a special grip of the soil, the asphalt can be substituted with reinforced grass paving Plastic lawn protection grids guarantee a certain firmness of the soil whilst allowing the grass to grow. This would also allow permeability to the soil, so that rain water can be collected and recovered. Radiation falling over vegetation is absorbed mostly by leaves; their absorption coefficient is 0.8, rather high, but instead of rising the temperature of leaves the radiation is "spent" in evapo-transpiration of water from the leaves. The radiation which impinges the soil is partly absorbed and partly reflected. The absorption coefficient is 0.4-0.8 and the moisture in the soil causes more evapotranspiration, so that the radiant temperature doesn't increase.

Shaded areas in the car park can:

- cool down radiant temperatures of the asphalt;
- prevent pedestrians having direct exposure to the sun which increases sweating ratio;
- keep cars from solar heat gains.

Shade in the car park is often created with the use of trees, however the amount of shade generated by singular tree elements is not extremely extended and it is not controllable. Canopies can be designed for car parks in a way that the shadow can affect a large area of asphalt, protect the customers walking and eventually prevent the cars from direct radiation, so they will no longer need a lot of energy to cool down The following drawing shows a design that can provide shade during late afternoon in cooling season, which is the highest occupancy time.

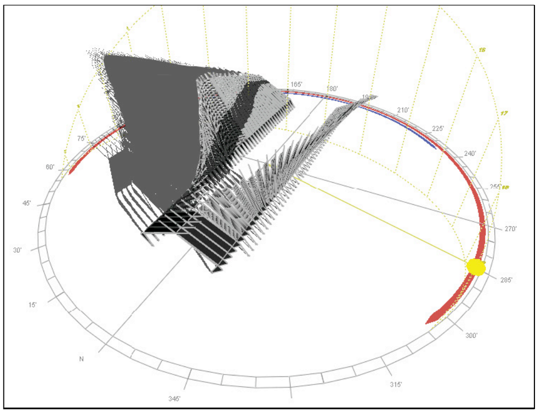


Figure 9 - Hypothesis for a canopy that provides shade on the car park whilst allowing flexibility in the parking areas

The effects of the change of surface materials and of the shadow were tested with EnviMet and comfort was assessed. Fig 11 shows how the canopy can become a sheltered passage, a passive space for further adaptation in preparation to the internal distribution area that required an extra effort in design.

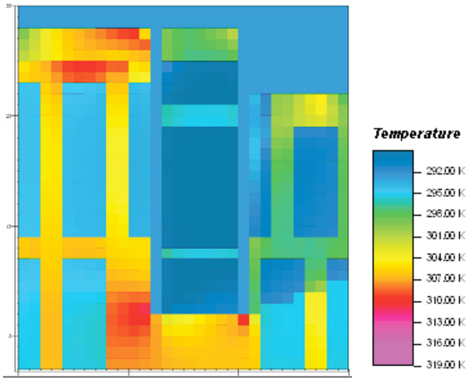


Figure 10 – Radiant temperatures in the car park

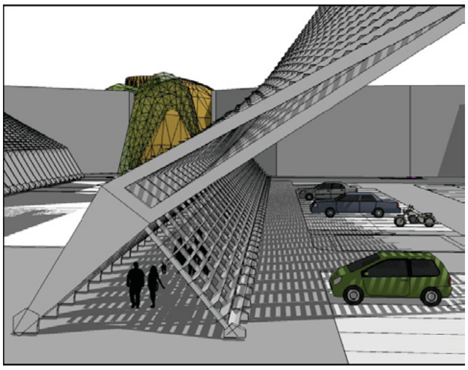


Figure 11 – Under the canopy, sheltered foot path

Similarly to shopping arcades, the design of the internal buffer space can be a zero energy space; this was tested with thermal modelling with the northern Italian climate throughout the year. Moreover its peculiar design provides natural ventilation, night ventilation to the shops (Fig 14) and provide at the same time daylighting to the corridor and to the shop front (Fig. 13).
Its benefits to the shops were simulated with daylighting and thermal software.

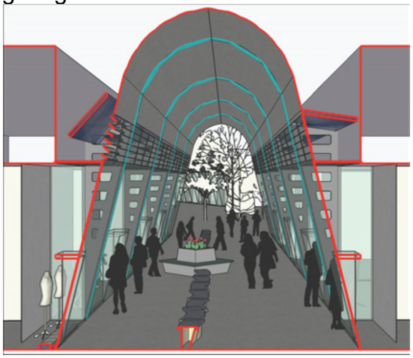


Figure 12 - Scheme of the internal buffer space

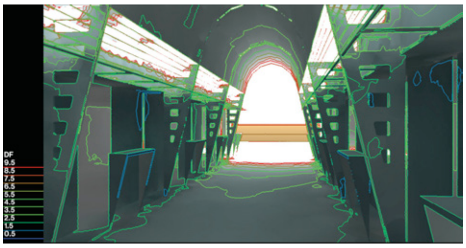


Figure 13 – Radiance simulation

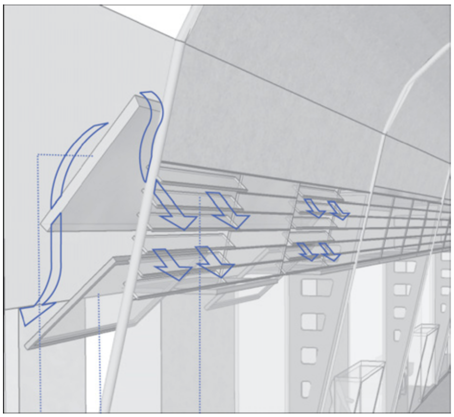


Figure 14 - night ventilation scheme

This design provides particularly a safe way for shops for night ventilation, with the apertures provided in the top of the shop front.

5. Conclusions

The intermediate thermal/environmental steps provide subliminal adaptation both to and from neutral conditions.
The psychological aspect becomes very important because the user realizes that he has an opportunity for a shelter. The foot path provides an improved environment and reduction of metabolic rate: the user walks more slowly as he feels safe from the car traffic and from the solar radiation. Inside the mall, the free running configuration is able to provide comfortable values also in the most critical climatic conditions. This scheme of the corridor brings daylight in a way that emphasizes the shop windows and gives sufficient illuminance values to the mall, with the consequent energy savings. A ventilation scheme as such is able to tackle heating gains where needed, with the advantage of supplying air at higher temperatures and with less ACH.

6. References

1. M. Wall, “Distribution of solar radiation in glazed spaces and adjacent buildings. A comparison of simulation programs” from “Energy and buildings”, no 2, 1997 Sept, p. 129-135, 1997
2. R.de Dear, G. Brager, D. Cooper, Developing An Adaptive Model of Adaptive Comfort and Preference, Final Report, ASHRAE RP/884, 1997
3. ASHRAE Standard, 55-2004, Thermal Environmental Conditions for Human Occupancy, ISSN 1041-22336
4. Yannas, S. (2000). Living in the city; urban design and environmental sustainability. Proceedings of PLEA 1998. James and James Science Publisher, London. Van der Linden