EPIC'98, Lyon, 19-21 November 1998

Design tools for outdoor comfort assessment

Jacques TELLER
University of Liege, LEMA (Laboratoire d'Etudes Methodologique Architecturales)
15, av. des Tilleuls, BAT D1, 4000 Liege (BE)

email : Jacques.Teller@ulg.ac.be
url : http://www.ulg.ac.be/lema/

Abstract. This paper discusses the questions raised by design tools development for outdoor comfort assessment. It is argued why this specific application field not only raises technical difficulties, i.e. the number of objects to be considered in traditional urban open spaces. Probably, conceptual difficulties are far more intricate. Actually, most present knowledge about thermal comfort appears largely inherited from stationary indoor experiments and calibrations. As such they neglect a number of critical aspects of urban design.

1. Introduction

Since the decline of the reliance on traditional zoning schemes, outdoor spaces quality has been raised as a major issue in the urban planning agenda (see [PUNT-97] for an extended discussion of this turnover). This specific urban concern has been termed 'urban design'. It already gave rise to a number of research publications as well as to the development of novel professional skills. *Urban design* is commonly defined through two different ways. First, through its scale which is considered as intermediate between architecture and traditional land planning. It is also defined through its scope. Urban design would specifically focus on the three-dimensional interactions between buildings and open spaces.

As such, this design field is always characterised by a number of *specific properties* [DUPA-96]. For instance, the number of objects to be considered in urban design is usually much larger than in architectural design. Furthermore, these objects are much more complex than land zoning ones, which mostly consist of 2D zones and networks, characterised by limited attributes (land use, accessibility, and so on). Furthermore, urban design is also uncommon through its basic procedures. Political, judicial and technical considerations are interwoven in such a way that none of these three aspects can be neglected for the effective implementation of any urban design scheme [TELL-98a].

This being said, urban design shares at least one common aspect with all other design fields, namely it requires some *instrumentation* for the various design alternatives to be specified and evaluated. In this perspective, some computers models were already developed for the assessment of specific urban design issues, i.e. visual integration [HILL-84], solar energy availability [TELL-98b] or open spaces enclosure characterisation [DUPA-97].

Yet, *outdoor thermal comfort* remains a critical issue just as now, even when defined in a quite narrow way, namely "that condition of mind which expresses satisfaction with the thermal environment" [FANG-72]. Actually, as will be discussed throughout the paper, thermal comfort characterisation usually relies on a holistic approach of the human environment. In outdoor spaces, this approach would mean that thermal comfort assessment could not be limited to specific control point and times, but rather require a comprehensive characterisation of a space thermal quality. Consequently, such a holistic approach unavoidably raises the issue of 1) thermal variables assessment and 2) these variables integration along the space and its various time of use.

2. Outdoor thermal variables assessment

One usually distinguishes between three main kind of *variables* for thermal comfort assessment : clothing, activity and environment variables (figure 1). Once properly defined these variables can be used for the thermal balance characterisation of an indoor space. Indoor thermal design consisting of adjusting the environment variables in such a way that they match the predefined clothing and activity levels by considering subjective satisfaction index for this thermal balance.

clothing	**activity level**	**environmental variables**
Rcl, fcl	metabolism air velocity	geometrical model
		ambiant air T° relative humidity air velocity
		surface temperature incoming radiation

Figure 1 - Traditional thermal comfort variables.

From an urban design perspective, these variables assessment raises a number of questions.

The first two variables, *clothing and activity*, are much less controllable in outdoor than indoor environments. Obviously this should not be a design parameter when the "public space", in his political sense, usually means the larger freedom to dress and behave oneself. Of course, one may recognise such a freedom in indoor spaces. Adaptive comfort precisely relies on individual variations, driven by personal strategies in order to seek for better comfort situations [HUMP-98]. Yet, indoor social control is basically submitted to private rules which, by definition, are commonly more stringent than public ones. In this sense, outdoor design should rather be compared with public buildings design than to office buildings design. In both cases, the problem will be to avoid an environment over specific to some kind of use, either in clothing or activity terms. Such an approach would thus require detailed sensitivity analyses of the thermal comfort according to various patterns of use and clothing, which is not really the way Fanger's equations are commonly used.

When environmental variables are to be assessed the problem gets even more intricate. We already noted that outdoor geometrical environment is usually much more complex than the four walls configurations often encountered in indoor design (see figure 2 for instance). In the previously mentionned holistic approach, such complex *geometrical environments* would need due databases and huge computer capabilities to be processed. Obviously, the geometrical environment could be simplified through some typical cases, but it has to be noted that the 3D shapes of the urban open spaces still remains the basic material of urban designers. Air temperature, wind velocities, relative humidity, all these air conditions are far from their control in usual conditions. Probably Sevilia EXPO'92 and other international fair led to limited air conditioning of outdoor spaces, but such experiments are exceptional. Moreover their sustainability is far from obvious just as now. Most high-tech thermal devices of EXPO'98 were indeed disrupted after the fair for instance.

From a modelling point of view, outdoor *air conditions* assessment is also very complex. Advanced CFD codes could probably help us, even with very complex geometrical models, but they always require very detailed knowledge about boundary conditions and advanced numerical skills in order to interpret results. As such they often appear as a wonderful way to understand physical thermal mechanisms occurring in a space, but the most cautious attitude should be adopted when applying them for predictive measurements.

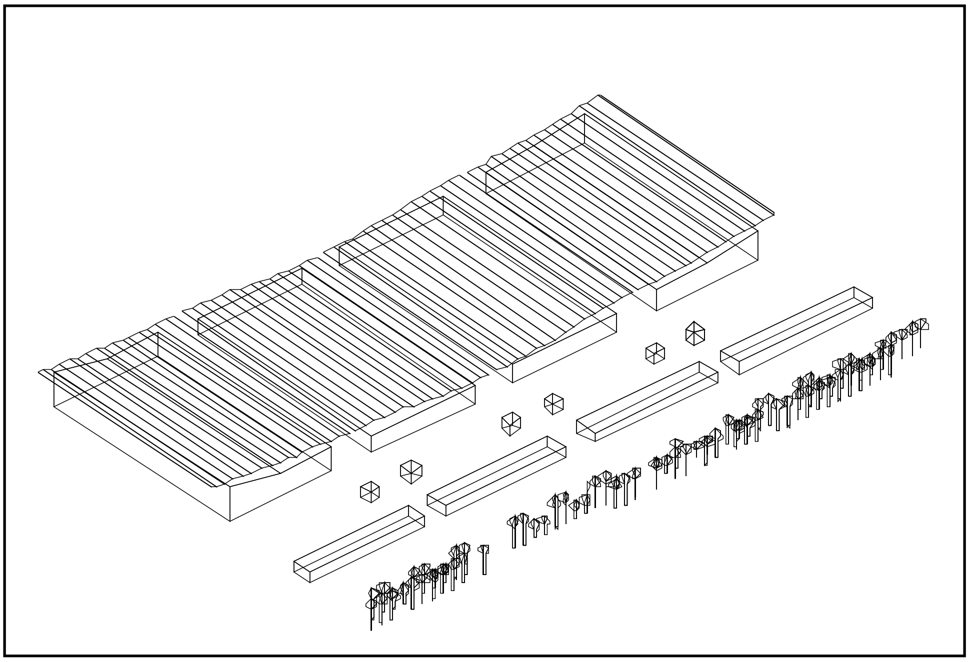

Figure 2 - TOWNSCOPE II axonometry of the site of LISBOA’98 international fair
(the central solar coverings were removed from this picture in order to improve
the legibility of the visualisation, but they make the geometrical model even more complex)

Finally, the last two environmental variables, *surfaces temperatures* and *incoming radiation* on the human’s body, are submitted to shortwave direct, diffuse and reflected radiations in outdoor spaces. According to Fanger, if the person is irradiated by short wave radiation, the human’s clothing reflectance has to be considered [FANG-72, p.35]. Here again this would probably require hardly sustainable assumptions for public spaces since the material colour plays an important role in its reflectance. But more basically, Fanger’s equations did not consider variable short wave radiation for they were only valuable in stationary conditions. Human’s reaction times to thermal environments modification wasn’t considered by his stationary model. Can we consider this as a valuable assumption in outdoor spaces ? Probably not, especially when we know that this model has already been questioned for indoor comfort by adaptive approaches [HUMP-98].

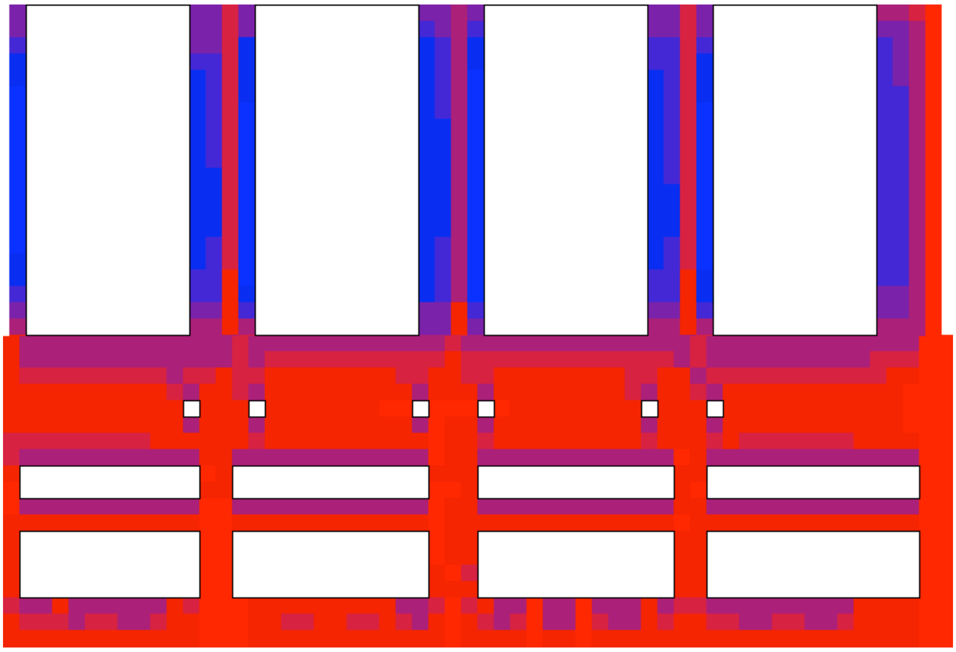

Figure 3 - TOWNSCOPE II daily direct radiation on the 15th of June (clear sky conditions) assessment for LISBOA’98 international fair

In addition to these time variations, outdoor energy gains are also variable along space (figure 3). Such spatial variations are often disregarded in indoor environments, for they mean to depart from optimal conditions in some places of the space. Yet, accepting some time and location comfort variations is really necessary in public spaces. Otherwise we probably would have to transform them in indoor environments as is the case for shopping malls and other retail centers [SCHI-98]. It means that the traditional FANGER'S approach for an environment thermal comfort characterisation is no longer satisfycing. In outdoor spaces, there is probably nothing like representative control points and times. Rather the environment has to be studied *along its space and time dimensions*.

3. Thermal variables integration

Let us now make this assumption that we would have solved all these variables assessment problems. Even since, there would remain a number of questions on how to "*globally*" characterise a space thermal comfort performances.

We obviously need some "integration mechanism" in order to decide if the open space complies with what is defined as a 'usual thermal environment' in adaptive comfort terms. In over simplified terms, we need some tool that integrates the numerous timely variables maps into a single one, or eventually a single ratio. For direct radiation, such an integration is often realised through the addition of timely radiations. This produces a daily radiation map, which can be used for buildings energy gains for instance. In comfort terms, such an integration immediately raises a number of questions since it is no longer possible to simply cumulate local results, either along space or time. Due to human's physiological and psychological reaction times, it is well known that a localised overheating for instance would not be perceived as such, either in time or space dimensions. It could even be welcomed by contrast with previous thermal situation, due to humans *expectations* and *memory* [NIKO-98]. And the problem gets even more complex when we consider that people are not just passive "subjective thermometers". They are very able to escape from limited discomfort situations by adopting appropriate *behaviours*, especially in public open spaces (to change one's walking side on a road for instance).
A number theoretical models have already been proposed to consider such phenomenons. They're often based on complex *mathematical computer techniques*, like intelligent agents , fuzzy logic or statistical considerations (see [HUMP-98] for an overview of these techniques). Yet there probably remains a huge amount of theoretical modelling for these models to be really transferable towards design tools.

Especially when we consider that what is needed by urban designers is not only predictive numerical results, but some instrument on how to *decide* which aspect of the design has to be modified in priority when the space doesn't match with thermal comfort requirements. In order to illustrate this demand, let's solely consider Fanger's iso-comfort graphs, which through a single image, visualises the whole indoor design solution space and the most appropriate strategies in order to match appropriate comfort levels. It is the same with stereographical projections, which not only represent the times and days of direct radiation, but also the most important masks and their location (see figure 4). In a short, such visual instrumentation not only afford information about the "what" of thermal performances of an environment, but also about its "why". This was the approach we adopted when redeveloping TOWNSCOPE for direct, diffuse and reflected radiation evaluation. It required the development of specific visual interfaces, specialised along one or another solar energy aspect (see [TELL-98b] for a description of such visual instruments).

Since the *political nature* of urban design, it has to be acknowledged that a clear understanding of the mechanisms underlying the numerical results is a very critical issue for design tools. Obviously, deciding whether it is better to have (in very naive terms) 50% of comfort during 100% of time or 100% of comfort during 50% of time is no longer an engineering debate when public spaces are at hand. Both these options could well be admitted according to various places, various uses, various intents in a word. In such a context, indoor optimisation strategies are probably no longer relevant. The engineer's role would rather be to provide relevant information in order to facilitate an argumented debate between the various interest at hand. This appear as a major shift in design tools terms.

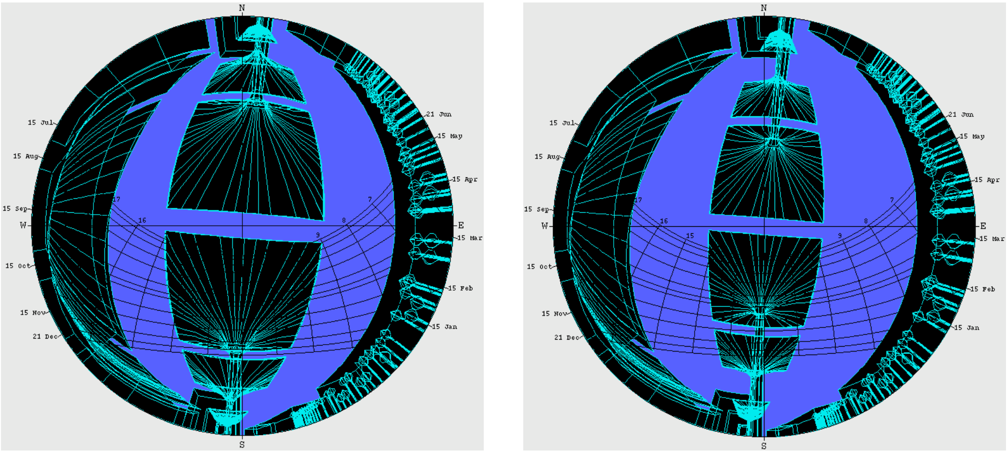

Figure 4 - TOWNSCOPE II solar paths visualisations of two coverings geometries in LIBOA'98 international fair

4. Conclusions

Design tools development for outdoor comfort assessment appear as a very intricate problem. It's been discussed how it raises technical, but also conceptual difficulties. When design options are no longer fixed, even through subjective considerations, but relative as is the case in all urban design projects, other instrumentation are needed. It has to be considered that the sensitivity of thermal variables to uncontrollable modifications combined with the difficulty to integrate these variables should drive us to reformulate comfort problems in a "risk theory formalism". We should thus shift from optimisation strategies to *robustness* strategies, in order to *minimise the risk of discomfort according to hardly controllable thermal conditions*.

5. References

[DUPA-96] DUPAGNE A., TELLER J., Représentation de l'espace ouvert dans un système d'information de projet urbain, *Ingéniérie des Systèmes d'Information*, vol 5 n. 2, juin 1997.

[DUPA-97] DUPAGNE A., JADIN M., TELLER J., *L'espace public de la modernité*, Études et Documents, Région Wallonne DGATLP, 1997.

[FANG-72] FANGER P.O., *Thermal comfort*, Mc Graw Hill, 1972.

[HILL-84] HILLIER B., *The social logic of space*, Cambridge University Press, 1984.

[HUMP-98] HUMPHREYS M.A., NICOL J.F. (1998), Understanding the Adaptive Approach to Thermal Comfort", to be published in *ASHRAE Transactions*.

[NIKO-98] NIKOLOPOULO M., BAKER N., STEEMERS K. (1998), 'Thermal comfort in outdoor spaces', *Proc. of PLEA'98*, Environmentally Friendly Cities, Lisbon, pp. 153-156.

[PUNT-97] PUNTER J., CARMONA M., *The design dimension of planning - Theory, content and best practice for design policies*, Chapman & Hall, London, 1997.

[SCHI-98] SCHILLER DE S., EVANS J.M. (1998), Rediscovering outdoor living space - Design from the outside in, *Proc. of PLEA'98*, Environmentally Friendly Cities, Lisbon, pp. 153-156.

[TELL-98a] TELLER J. (1998), The St-Michel reconstruction project in Liège : a morphological regulation case study, *Tempus Seminar in Timisoara*, June 4-6 (available from the author).

[TELL-98b] TELLER J., AZAR S., (1998) TOWNSCOPE II - A computer system to support solar access decision-making, to be published in *Solar Energy Journal*.