

Dial-Europe— European daylighting design tool

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Abstract: Started in April 2000, the European project DIAL-Europe [1] was funded by the European Commission within the framework of the FP5 Program: Energy, Environment and Sustainable Development (Contract No. ERK6-CT1999-00007). It ended in April 2003 with the achievement of a new daylighting design software meant for building designers.

The aim of this intuitive tool is to give relevant information regarding the use of daylight, at the very first stage of the design process.

DIAL-Europe focuses on the following specific targets

- Daylight factor calculation (CIE overcast sky),
- Estimation of the annual daylight sufficiency (based on climatic data),
- Prediction of summer overheating,
- Estimation of artificial lighting contribution,
- Optimizazion process (Diagnosis based on fuzzy-logic rules)
- Comparison with presimulated case-studies.

This paper presents all these parallel work packages and gives an overview on the final version of the tool, which is now available.

Keywords: daylighting design, early design stage, intuitivity.

1. Objectives

The primary objective of the project was to develop a daylighting design tool which, by being compatible with the design approach of architects, would assist in the early design of windows in buildings, and leads to better energy and environmental performance. As well as daylight performance, the tool also indicates other environmental factors associated with windows, such as overheating risk, and includes artificial lighting design and its integration with daylight.

2. Intuitive interface

To make the input process as simple as possible, the intuitive interface of LesoDIAL [2] has been refined and developed (see Fig.1). This allows the user to either select graphic or linguistic items as well as precise figures. Thanks to this very user-friendly interface any non-specialist user is able to quickly describe the room he wants to analyse. In case of misunderstanding, hyperlinks with an illustrated Glossary are used to explain the various lighting topics (see Fig.2).

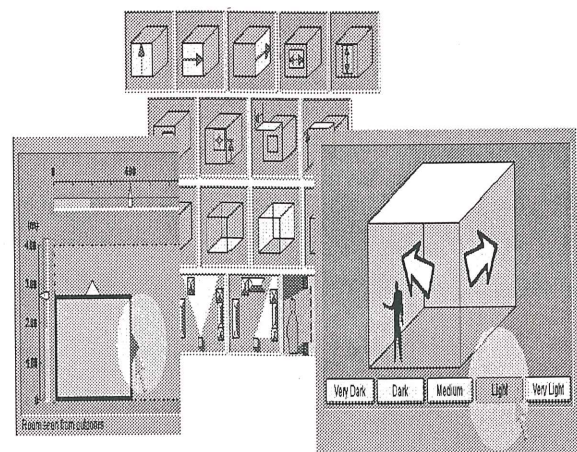


Fig. 1 Example of the intuitive input used to describe the room.

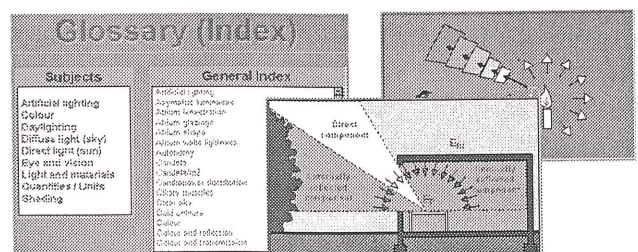


Fig. 2 Screen shots of the Glossary

3. Daylight factor calculation

The daylight factor calculation is based on a split-flux method. The direct component of the daylight factor (sky component) is calculated thanks to an analytic formula [3]. The outdoor reflected component is calculated in the same way and is weighted by the average reflection coefficient of the outdoor obstructions. The indoor reflected component is calculated with a simplified formula [4]. This calculation method leads to real time calculation and is particularly well adapted to conduct parametric studies and to test various configurations very quickly.

4. Annual daylight sufficiency evaluation

The overall objective was to develop a method allowing the user to know the time during which the illuminance requirements could be satisfied thanks to daylight.

Meteorological data from Meteornorm [5] has been used to adapt the daylight autonomy calculation to a large number of locations throughout Europe. The calculation is based on the external horizontal diffuse illuminance. Polynomial functions describing the cumulative probability for outdoor diffuse illuminance to reach a given level are obtained for each location (see Fig. 3).

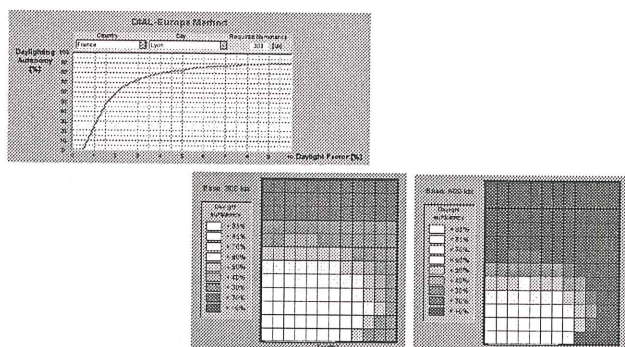


Fig.3 : Example of polynomial function used to link the daylighting autonomy to the daylight factor value. Comparison of the Annual Daylight Sufficiency (Autonomy) in a given room, for two required illuminance levels (respectively 300 and 500 lux).

Data from approx. 150 cities in 17 European countries is available, and the countries covered so far include: Austria, Belgium, Denmark, France, Finland, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the UK.

Data for other locations can be added very easily.

Thanks to these functions, the annual daylighting sufficiency is estimated, based on daylight factor

values and with respect to the required indoor illuminance. The implementation of orientation factors, based on the European Daylighting Atlas data, is used to adapt the result to the facade orientation.

5. Artificial lighting

The overall objective of this work package was to develop an artificial lighting design tool which would be compatible with the level of input and output detail in the daylighting tool. Within this work package DIAL-Europe is also able to provide guidance on qualitative aspects and visual comfort, switching controls and integrate them with daylight.

Work has been undertaken on the development of generic lamps and luminaires.

The user is able to specify the light distribution required within the room, the colour of the light and the type and location of the luminaires. After the user has selected the source and luminaire of his or her preference, s/he can determine how many luminaires must be positioned of this type and also the distance between floor and luminaire(s).

The 'Lumen method' is then used to estimate the illuminance level of artificial lighting. Calculation routines have been implemented to evaluate illuminance levels on each of the room faces (including work plane).

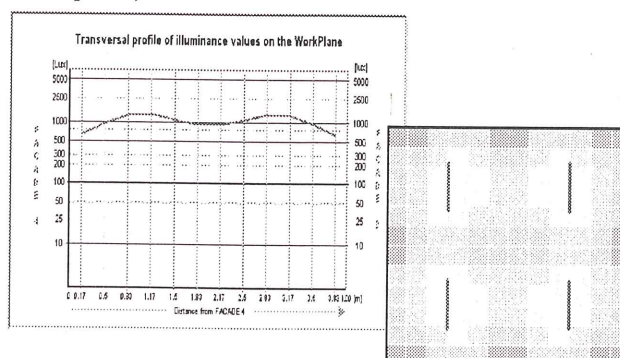


Fig. 4 : Example of illuminance distribution calculated with the artificial lighting tool.

In addition to this, more than 50 diagnostic 'expert rules' have been developed that help the user to optimize the artificial lighting components. The rules are built as IF-THEN statements and either generate lines in the 'diagnosis' field of DIAL-Europe.

6. Overheating prediction

The overall objective of this work package is to indicate the thermal implications (heating and cooling energy and thermal comfort) of the proposed design

with a level of input and output detail compatible with the daylight tool.

Following a detailed analysis of the Admittance Method and the Free-floating Internal Temperature Method, it was decided to programme and implement a simple 3-node resistance network method (RNM) into the tool, in order to calculate the overheating risk.

The model takes into account the solar gain, lighting gain, climate data and ventilation rates within the room, as well as its thermal mass and occupancy pattern. Users of the software are then warned of the overheating risk of their design.

Comparisons have been made with the results from ESP-r, for the analysis of energy and mass flows, on light, medium and heavyweight rooms. Figure 5 shows that the results are very favourable.

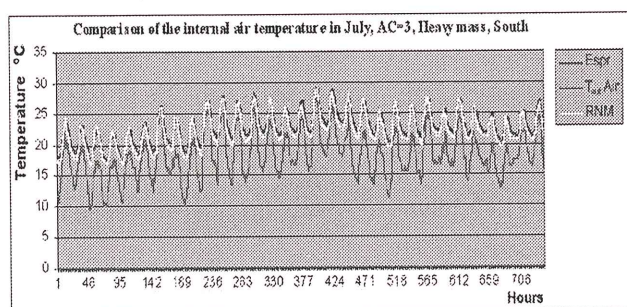


Fig. 5 : Comparative results between the RNM and ESP-r methods.

7. Optimization facility

For each of the modules described before, expert rules, based on fuzzy logic statements have been implemented to prompt the user to optimize the design. Figure 6 shows an example of a fuzzy set that is used to describe the overheating risk as a function of the number of overheating days. Table 2 shows the different linguistic items (verbs) that are used to qualify the strength of the incentive message delivered to the user.

Those kind of fuzzy sets are used to build fuzzy rules such as shown in Fig.6, and that might be expressed as follow:

- IF Overheating Risk is "Very High"
- AND Shading coefficient is "Medium"
- THEN The user "COULD" reduce the g coefficient of the shading device.

Many other parameters as orientation, glazing ratio, shading device and ventilation strategy, etc. are used in this optimisation process to reduce the overheating risk.

The same strategy is applied to optimize the annual

daylight sufficiency as well as the artificial lighting. Thanks to these facilities the use of DIAL-Europe give to the users a real opportunity to improve their design and leads to a better architectural quality.

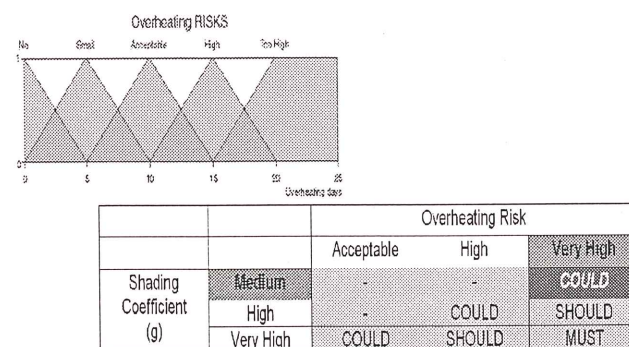


Fig. 6. Example of fuzzy set used to describe the overheating risk as a function of the number of overheating days (top left) and example of decision table used to build the linguistic diagnosis (bottom right).

8. Case studies database

The overall objective of this work package is to allow the user to visualize some examples that are similar to their project (see Fig.7). From a general point of view, the possibility to compare different solutions offers a very efficient way to highlight the possible positive or weak points of a project.

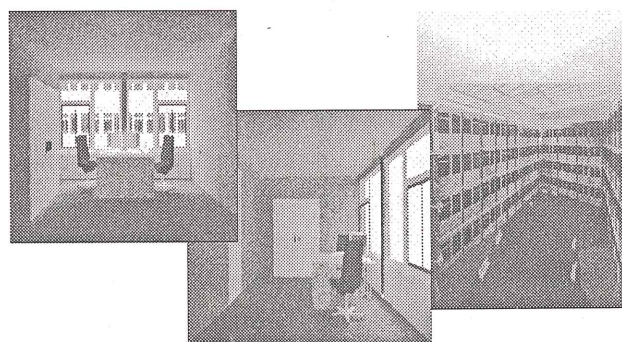


Fig. 7. Example of Radiance simulation rendering used to illustrate case-studies stored in the database (here rooms in an atrium).

More than 250 case-studies are stored into the 3 following databases:

- Real buildings (monitored rooms)
- Simulated rooms (Radiance simulations)
- Simulated atriums (ADELINE simulations)

The concept of "fuzzy outranking relation" has been used to match the room described by the user with case(s) stored in the databases that present some similarities. Each case-study is looked at, parameter by parameter, and depending on its characteristics, is

considered as "concordant" or "discordant" with the user's room (reference).

More information about fuzzy logic rules applied in DIAL-Europe can be found in [6].

9. Conclusions

We, as specialists, see more and more architects demanding simple tools to optimise the use of daylighting inside buildings, as early as possible in the design process. There is a real tendency to check daylight availability in buildings during their conception. Where environmental quality "labels" do already exist, for example HQE in France, precise information on daylight is required from designers.

Due to its philosophy for simplicity, rapidity and intuitivity DIAL-Europe is in a very good position to fulfil this demand.

If it is extremely difficult to estimate the direct impact of a design tool, the potential for energy saving from the use of daylight can be readily demonstrated. We can consider that if after one year of availability on the internet 1000 copies have been distributed, but suppose only 10 % of these influenced designers to improve the use of daylight in new medium-sized (2000 m²) buildings from 'typical' to 'good'. We will assume that here 'typical' means almost no use of daylight and 'good' assumes a conservative 50% reduction in lighting energy.

In a survey of office buildings in the UK, BRESCU (Building Research Establishment Conservation Support Unit) gives typical yearly lighting energy consumption as an average 54 kW·h/m² delivered electricity. Thus, at the end of one year, with 100 copies in active use, we could see potential savings of $100 \times 2000 \times 54 \times 50\% = 5.4$ GWh/year. Assuming that the approximate cost of electricity is 0.12 Euro/kW·h, the value of this saving is $5.4 \times 0.12 = 0.65$ m Euro a year.

This compares favourably with the total cost of the project, which stands at 0.7 m Euro. Assuming that the

savings go on accruing in subsequent years, and that the use of the tool continues as in the first year with 1000 copies being marketed but only 100 being actively used, then the saving in ten years would be 35.75 m Euro. This equates to an electricity saving equivalent to 0.25m t of CO₂.

Acknowledgments

The author wants to give a special thank to all the members of the DIAL-Europe team, namely:

- Nick BAKER, Sam LAWTON, Mike McEVOY and Runming YAO, from The Martin Center for Architecture and Urban Studies, University of Cambridge (UK).
- Jan de BOER, Hans ERHORN and Simon WOESNER, from Fraunhofer Institute für Bauphysik, Stuttgart (D)
- Ellie de GROOT and Laurens ZONNEVELDT from The Netherlands Organisation for Applied Scientific Research, Eindhoven, (NL)
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References

- 1 Paule, Scartezzini, Reynolds, Baker: "Handling daylight in the early design stage", Proceedings of the Eurosun-2000 conference, Copenhagen, June 2000.
- 2 Paule, Scartezzini, "Leso-DIAL Daylighting Design software", Proceedings of the Daylighting'98 Conference, Ottawa, Canada, May 1998.
- 3 Hopkinson, R.G.: "Architectural Physics : Lighting", HMSO Her Majesty's Stationery Office, London, UK, 1963.
- 4 BRE British Research Establishment : "Estimating daylight in buildings" : Parts 1 - 2, Digest 309, 310, Building Research Station, Garston, Watford, Hertfordshire WD2 7 JR, England, 1996.
- 5 Remund, Lang & Kunz, "Meteonorm software" Copyright Meteotest CH-3012, Bern, Switzerland, Nov. 1999.
- 6 Paule, «Application de la logique floue à l'aide à la décision en éclairage naturel», Phd Thesis, Swiss Federal Institute for Technology, EPFL, Lausanne, 1999.