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A Lighting, Thermal and Ventilation (LTV) Design tool for non-domestic buildings in tropical and subtropical regions

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Abstract

The paper reports on progress to date on the development of a model for predicting energy use and the effect of conservation strategies in non-domestic buildings in the tropic and subtropics. This model considers lighting loads (L), both artificial and daylight, thermal loads (T) and ventilation effects (V).

It is hoped, that when completed in late 1998, the model will provide a Lighting, Thermal, and Ventilation (LTV) advocacy tool for use in the early stages of the design processes of engineers and architects. This will provide vital feedback to the early design decisions.

INTRODUCTION

The rising concern for energy efficiency in buildings has prompted research into ways of minimising the use of active environmental control systems such as refrigerant air conditioning to provide thermal comfort and artificial lighting in buildings. The predominant and extensive use of these systems in large, complex, non-domestic buildings has led to concern that these buildings are environmentally irresponsible. Climatic design strategies have been developed to introduce the use of passive features into these buildings such as shading, insulation and natural lighting to minimise active systems. At present there are no models that predict the effects of these strategies on energy use in tropical and subtropical climates.

Furthermore, for these strategies to be adopted by designers, evidence of the relative performance of each strategy is required at the conceptual design stage of the building. At present it is common practice for complex buildings to be designed with little regard for energy use and then energy saving features added at a later stage. This is usually ineffective or problematic. It seems crucial therefore for a design tool to be developed for the early stages in the design process. Such a tool would need to be based on predictive models of energy usage for non-domestic buildings in tropical climates.

The broad intentions of the current research is to develop a model of the interplay between climate, building form, building occupancy and energy use for complex buildings. As a first step, the energy behavior of various representative buildings is being assessed by computer simulation using a parametric study. The computer simulation program is ESPr (University of Strathclyde). This program is a building and plant energy simulation package which is under continuing development at various research centres throughout Europe. It is the European Reference Model for building energy simulation.

APPROPRIATE CLIMATIC DESIGN

Research has been carried out in Europe and North America on developing appropriate climatic design strategies for complex buildings. One research project particularly relevant to this current work is the development of the LT Method [1]. The LT Method is a design tool for predicting the contribution of passive features of building design to the energy usage in buildings. The method is calculation based (in spreadsheet form) and provides likely absolute energy usage values for non-domestic buildings such as offices.

No work has been carried out into developing a model and a design tool for the warmer climates of the tropic and subtropics. This current project draws on the existing work in the UK and advances this in the area of Australian and SE Asian building design practice where these climates predominate.

The research methodology of the LT project is used in this current work, but its form and content are likely to be very different as the LT Method is based on European climates.

The importance of this work to Australia is considerable. This is emphasised by a recent initiative by the Energy Research and Development Council [2] contract for a *Tropical Building Innovation Program*. The need for this project has come about due to the lack of research and environmental best practice information in the tropical and subtropical parts of Australia, available to designers. The use of the LTV Model under development in this project will provide invaluable input into this area.

It is the practical nature of this work that is important. At present there is a lack of design tools for assessing the implications of climatic design decisions made at the conceptual stages of the design process. This means that decisions concerning the passive design features and selection of active systems are taken after the conceptual design phase and therefore retrofitted to the building fabric. Developing design tools that are simple and effective at the early stage of the design process is imperative to the successful integration of climate and energy efficient strategies. At present there are a number of computer based simulation programs that can evaluate buildings design from an energy point of view and give feedback to designers. The problem is the complexity and precision of these programs prohibits their use at the conceptual stage where simple but effective tools are required to assist with the looser iterative process of design at that point.

The LTV Model, when complete, will be used to develop an advocacy design tool in a similar manner to the LT Method.

The advantages in terms of design process will be complimented by the greater emphasis offered by such tools in the area of passive building design. At present both engineers and architects prefer to rely on active systems (air conditioning, etc.) because of the simplicity in the design process. This often results in profligate energy use. [3] A simple quantitative method that assesses the contribution made by passive energy saving features incorporated in the design (such as shading, light shelves and buffer zones) on the energy budget for the building is required. This has the potential not only to improve energy efficiency but also support design decisions and provide further evidence of building efficiency for client discussions.

ENERGY CONSERVATION

There has been little work in developing models and design tools for non-domestic buildings such as offices, resorts and buildings of public assembly. Currently, work is underway to develop methods of providing energy standards in these complex building types with the provision of a Building Energy Code of Australia (BECA). However, there is little consensus on the form of BECA at present, although there is an intention to develop aspects of the Code specifically for commercial buildings [4]. It is suggested that one reason for this impasse is the lack of available models that can represent in a simple manner the complex and subtle interplay of climate, building form, building use and energy consumption.

The LTV Model draws on and extends the theoretical and applied work carried out in Europe. In particular, research collaboration has taken place between The University of Queensland and the Universities of Cambridge and Manchester, to assess the feasibility of the proposal. Discussions in 1994 at the School of Architecture, Manchester University [5] led to links with the *Martin Centre, Cambridge University*. Work in 1996 by N Baker, R Hyde and M. Docherty established the feasibility of the research proposal [6] [7]. The outcome will be to develop a climatic design model and tool, which will have wider national and international relevance. The basic climatic data will now include not only temperate climates but also subtropical and tropical climates giving the model a wider international relevance.

This work will link with a similar project being carried out by Professor Peter Woods, *Centre for Low Energy Design*, School of Architecture, Faculty of Engineering, University of Malaya, Kuala Lumpur, Malaysia. The scope of the Malaysian study is to investigate climatic zones in the hot humid regions to complement the work in Queensland on subtropical, tropical and hot arid climates.

CLIMATIC REPRESENTATION.

The selection of representative climates for this project has involved two stages. Firstly, classification of tropical and subtropical climates into representational zones. Work on this has been carried out by other researchers [8].

ESPr has the capacity to use actual hourly data for a complete representative year. The simulation runs can use subsets of a full year climatic data and incomplete data can be extrapolated as required. Appropriate data sets on the representative climates have been obtained from the Commonwealth Scientific Industrial Research Organisation (CSIRO). The CSIRO data obtained gave us hourly data for 78 locations within Australia, 3 locations in Papua New Guinea, 4 locations in New Zealand, Singapore, Hong Kong and a number of locations throughout the SW Pacific region. No substantive work has been carried out on developing representational climatic zones for Malaysia. Preliminary work, in collaboration with Professor Woods, has suggested

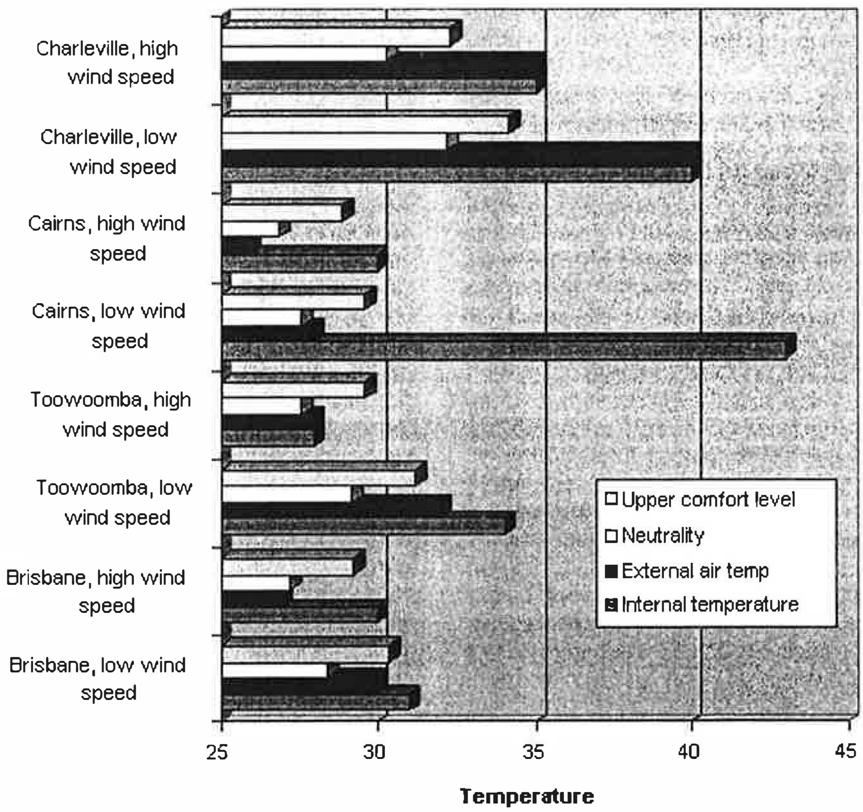

Figure 1 A small office in Qld; 2 weeks in summer. Comfort levels related to peak temperatures for standard construction in the Fover area.

that two zones will be appropriate. The relevant data sets are available from the University of Malaya.

The second step was to take the climatic data for each representational climatic zone and translate into data sets with the parameters required for ESPr. The CSIRO data included dry bulb, wet bulb temp, absolute moisture content, atmospheric pressure, wind speed, wind direction, total cloud cover, global and diffuse irradiance horizontal plane, direct irradiance normal plane and solar altitude and azimuth.

ESPr requires diffuse solar on the horizontal (W/m^2), external dry bulb temperature (Tenths °C), direct normal solar intensity (W/m^2), prevailing wind speed (Tenths m/s), wind direction (clockwise degrees from north) and relative humidity (%). (The calculation to convert from atmospheric pressure to relative humidity was suggested by S V Szokolay).

OVERHEATING MODEL

In each of the climatic zones, four office buildings are being surveyed to identify the 'default values' [9] for the computer modelling. Office buildings have been selected for study as this building type is a more standardised building type and there is concern over energy use. The additional parameters identified are, room height, glazing ratio, glazing bars, glazing type, workplane height, reflectance's, illuminance datum, U-values, heating and cooling set point, heating and cooling efficiency, cooling system, CoP, fan energy, lighting power heating load, occupancy and equipment heating load.

The main focus of the research has become the development of the 'overheating' model; this is being developed as a function of the following parameters.

1) Local Climate
2) Orientation
3) Area and type of glazing
4) Shading
5) Obstruction by adjacent buildings
6) Atrium conditions
7) Occupancy function and user patterns
8) Lighting levels
9) Internal heat gains.
10) Ventilation rate.

A series of 'experiments' using computer simulation are being run on a number of reference rooms within each office building, varying the above parameters, but keeping the default values constant. Finally, we will be able to predict annual primary energy consumption per square meter of floor area in each building.

Although we are at a very preliminary stage, a number of points are evident from our initial analysis. Firstly, In Brisbane, latitude 27°S, higher mass buildings have a reduced peak temperature on low wind days during summer. However, in Toowoomba, also at a latitude of 27°S, but altitude 200m , the temperature peaks mid-morning on low wind days for all construction types during summer and the higher mass building offers some time lag in winter when ventilation is negligible. In general, the effect of mass is negligible during summer, with high ventilation rates, for office buildings in latitudes above 20°.

Note also, that where there are large casual gains, these gains dominate the thermal performance of the particular building zone, and are more significant than the thermal mass. However, high ventilation rates mitigate this effect.

As an example of the output we have been using for analysis, Figures 1 & 2 are for a single storey, non-airconditioned office building in various locations, latitude between 27°S and 17°S. This building uses lightweight construction, and high ventilation rates. The windows are generally half open from 9am until 5pm

It is this interaction of the various ventilation effects that are most significant to the final resolution of the LTV model.

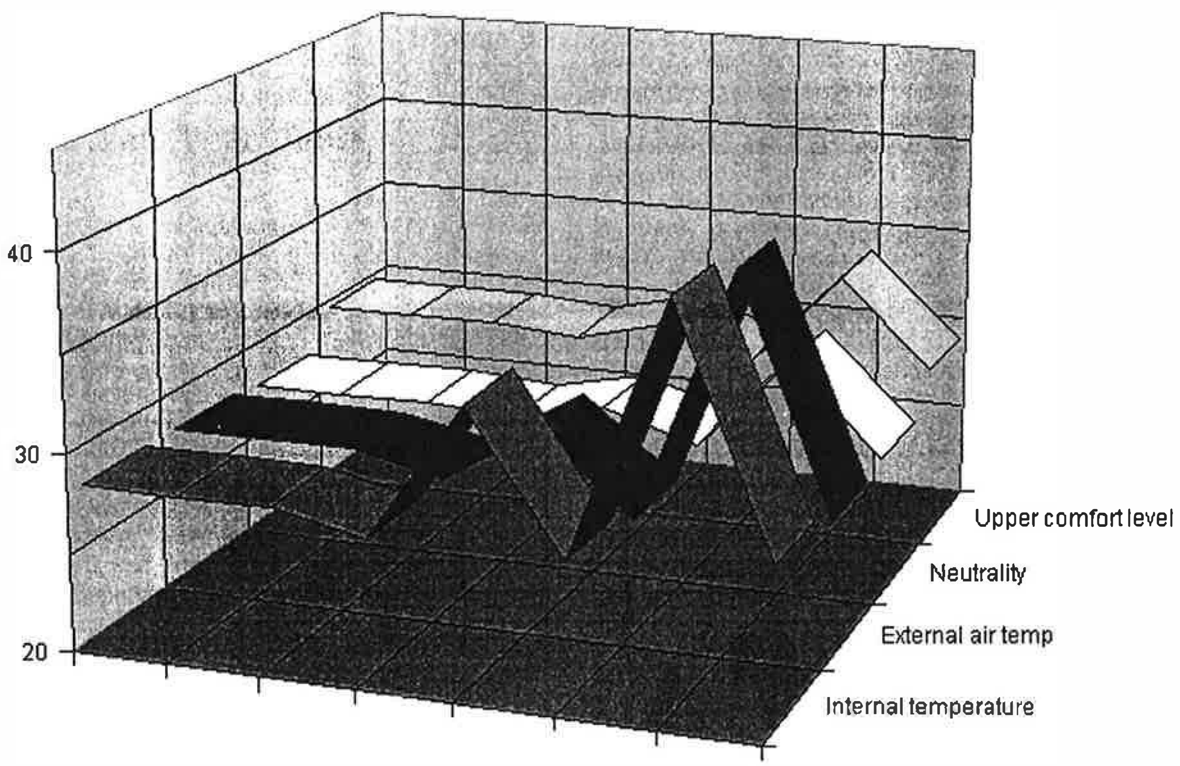

Figure 2 A small office in, Qld; 2 weeks in summer The effect of solar radiation on air temperature within the Foyer.

LTV MODEL DEVELOPMENT

To enable the LTV Model development our strategy has been to define a number of reference rooms for the complex buildings under investigation, typically office buildings and buildings of public assembly. A large series of simulation runs are being carried out to establish the thermal performance within the reference rooms. Parameters concerning artificial lighting, building form, building fabric, ventilation, etc, are varied and the data on thermal performance is assessed. By using the different climatic data and running a number of computer simulations of the performance of these reference rooms and parametric variations, it is possible to assess, on a comparative basis, the impact on likely energy use and thermal comfort of occupants. This forms the basis of the parametric LTV Model.

The final LTV tool will comprise a number of procedures for assessing the energy use of the proposed building through the use a series of graphs and spreadsheets. The designer can use the tool as a comparative evaluation method for the selection and manipulation of the climatic design parameters and derive likely energy savings or dissavings for the design. In this way, through an iterative process, a preferred design solution can be achieved.

However, the final LTV tool need not use a computer program to assess energy needs. A paper based, simplified calculation based method is possible. Similar to the LT Method, the heart of the tool will be a series of graphs, called LTV curves, which give the annual primary energy consumption per square meter for facades orientated for north, east/west, and south plus one for horizontal glazing. The LTV graphs will present the various parameters that the designer can manipulate: lighting, heating, ventilation and cooling in selected climatic zones. The tool will therefore be relatively simple, and it is this simplicity which is crucial to the effectiveness of any design tool. A number of assumptions are built into the existing LT Method [9] and the LTV model on which the LTV tool will be based must also incorporate necessary simplifications and limiting assumptions to enable an effective tool. Designers will be made aware of those assumptions to enable effective design decision making.

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