An Approach to Low-Energy Architecture for Commercial Buildings in Vietnam

Viet Tuan Do[1] and Alan N. Young[2]

[1]Architect, Building Energy Analyst, Sustainable Energy Action Ltd (SEA/RENUE), London, UK
KTP Associate, London South Bank University, London, UK
[2]Senior Lecturer, The Bartlett School of Graduate Studies, University College London, London, UK

ABSTRACT: The construction sector in Vietnam is currently responsible for about 30% of total CO_2 emission in the country, and is therefore a target for CO_2 reductions. As the result of an economic boom in Vietnam, many new commercial buildings are being constructed in Hanoi and Hochiminh City (HCMC), the two biggest cities in Vietnam, making their level of sustainability of particular importance.

Although there is a growing awareness among Vietnamese architects of environmental issues, there is a lack of readily available information and design tools to enable the design community to achieve low-emission and energy-efficient buildings. It has been perceived that a simple and user-friendly calculation tool, which can be used at the early stages of design, would be very useful to enable architects to formulate the most appropriate design strategies and solutions. This paper describes the development of such a tool and sets out some results of its use.

The aims of the paper are twofold: firstly it summarises the results of parametric studies investigating the effect of design variables on the total energy performance of office buildings in Vietnam using the computer simulation tool, TAS (Thermal Analysis System, a dynamic thermal simulation software). Secondly, the paper documents the procedure used for the development of the design tool called SLEADT (Simplified Low-Energy Architecture Design Tool) that has been developed based on computer analysis and explains how it should be employed. This design tool is capable of optimizing critical design decisions such as the distribution of glazing and the effect of orientation on energy loads.

Keywords: Sustainability, Sustainable Architecture, Low-energy Architecture, Environmental Performance, Computer Simulation, Design Tool, Commercial Building

1. INTRODUCTION

Whilst being able to make a contribution to the creation of more sustainable human habitats, architecture alone cannot solve global environmental or sustainability problems. Sustainable architecture is therefore a complex concept for architects. The practice of Norman Foster and Partners (1999) defined sustainable design as creating buildings *"which are energy-efficient, healthy, comfortable, flexible in use and designed for long life"* [5]. Thus, in the definition of sustainable architecture or sustainable development, energy resource takes a role as an initial and core factor.

Energy efficiency plays an important role in developing economies like Vietnam's, as these economies are more sensitive to any worldwide policy of reduction in energy consumption. The challenge for Vietnam is that, although being a relatively resource-rich country, it should strive to develop the energy sector along an environmentally sustainable path. Vietnam has to invest almost 5.3% of its GDP, twice the rate of its ASEAN neighbours, in energy infrastructure to keep up with the development rate of the region [8].

The Government of Vietnam is committed to environmentally sustainable development and energy efficiency as indicated by their ratification of the United Nations Framework Convention on Climate Change (UNFCC) on the 3rd December 1998. As part of their related efforts, the former Ministry of Science, Technology and Environment (MoSTE) participated in the Asia Least-cost Greenhouse Gas Abatement Strategy (ALGAS) which identified energy efficiency as a key priority. The Decree No. 102/2003/ND-CP on Energy Conservation and Efficient Use was promulgated in September 2003, developing and submitting to the government a five-year plan for energy development based on efficiency. Recently in November 2005, the first generation of an energy efficiency building code in Vietnam (the QCXDVN 09:2005) came into force.

2. ENERGY IN THE BUILDING SECTOR

Whilst overall energy consumption in Vietnam is not large by current global standards, the country is now among the fastest growing economies worldwide and energy requirements are growing at staggering levels. The building sector energy consumption, though a relatively smaller percentage of overall energy consumption today, is increasing rapidly as the economy of Vietnam progresses and the demand for modern facilities and office space increases.

Older buildings in Vietnam have employed more traditional design practices and have limited central air conditioning (and thus have had relatively low energy use). Meanwhile, newer buildings are expected to require substantially more energy to support modern comfort and technology requirements.

Public buildings represent a larger share of the market from an energy consumption standpoint. However, this segment does not represent a short-term commercial market for energy-efficiency retrofits due to such issues as the limited ability for financing and budgetary support, centralised decision-making, lack of life-cycle cost analyses for equipment purchase and lack of incentives.
Meanwhile, commercial buildings (hotels and offices), though a smaller share of the total market, represent a more commercially viable short-term opportunity for energy-efficient service providers due to the fact that investment decision-making is possible (companies are mostly privately-owned) and many owners are creditworthy.
The above analysis shows the importance of commercial buildings in the total energy consumption of Vietnam and highlights the focus of this paper.

3. EXISTING COMMERCIAL BUILDINGS

Vietnam is located in the centre of South East Asia between the latitudes of 23.22˚ and 8.30˚ north, lying in the eastern part of the Indochina peninsula. According to the climate classification system in the Building Code of Vietnam (Appendix 2.1, Vol.3, 1998), the climate in Vietnam is classified into five zones. Hanoi (the representative for the northern region of Vietnam in this study) is located in zone A3 and has a humid tropical monsoon climate with four distinctive seasons. Hochiminh City (HCMC - the representative for the southern region of Vietnam in this study) is located in zone B5 and has a typical humid tropical monsoon climate without a cold winter, but a distinctive dry season and rainy season annually (Figure 1).

Vietnamese architecture has had a history of constant development for more than 20 centuries. The vernacular architecture which is responsive to hot humid climates in which cooling and natural ventilation are priorities has much to teach the modern designer. Unfortunately, during recent years, the "international style" with fully glazed facades has become a popular trend among Vietnamese architects, as can be seen in Figure 2. Meanwhile, international design teams are almost always insensitive to local climate conditions when designing buildings for Vietnam, often resulting in unnecessary discomfort and energy waste.

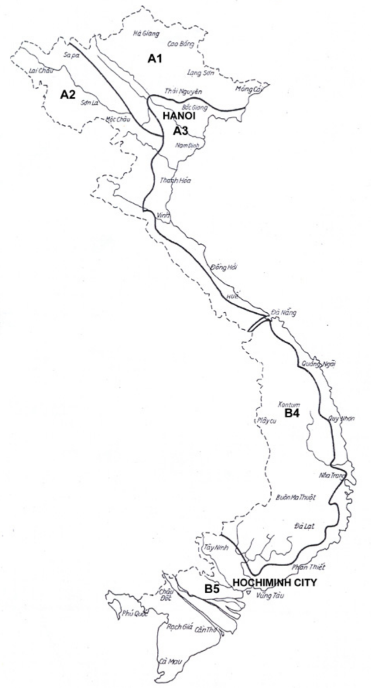

Figure 1: Climatic zones in Vietnam (Building Code of Vietnam, Appendix 2.1, Vol.3, 1998)

Alongside the economic reinvigoration ("Doi Moi" in Vietnamese) launched in 1986, the Government withdrew from providing subsidies for housing and encouraged people to buy and build their own houses. At the same time, it started to attract foreign investment in construction projects in Vietnam. This ushered in a boom in construction in Hanoi and HCMC. From 1990 to 1994, Hanoi construction grew at an 11% annual rate, whilst HCMC grew much faster at an annual rate of almost 23%. Since 1995, the comparative growth in commercial building construction in the two cities has continued at about the same rate [7].

Figure 2: New high-rise buildings in Hanoi and HCMC (picture taken by the first author)

Although there is a growing awareness among Vietnamese architects about energy and environmental issues, there is a lack of readily available information and design tools to enable the design community to achieve more energy-efficient and environmentally friendly buildings. It has been perceived that a simple and user friendly calculation tool, which can be used at the early stages of design, would be very useful to enable architects to formulate the most appropriate design strategies and solutions. The creation of such a design tool is the main purpose of the study in this paper.

During the period from 2000 to 2002, the first author of this paper participated in two commercial building surveys (called phase I and II) conducted by the Research Centre for Architectural Indoor Climate and Environment (RCAICE) of Hanoi Architectural University (HAU) and EnerTeam (Energy Conservation Research and Development Centre, HCMC Department of Science and Technology). The following discusses the findings of the two surveys [7].

The surveyed buildings in phase I represent almost all large-sized (> 5000 m^2, with 10 storeys or more) and medium-sized (2000-5000 m^2, with 5-9 floors)[1] buildings in each city. Based on statistics from the Chief Architect Bureau and the Department of Science and Technology in each city, these buildings could possibly represent about 25% of the total number of commercial buildings constructed in the two cities since 1990, and about 60-65% of the total floor area [6].

The main results of the phase 1 survey for office buildings are analysed below.

(i) *Fenestration:* Large, foreign-designed office buildings typically have glazing ratios in excess of 25%, with some approaching 80-90% (e.g., Sunwah Tower and Metropolitan building in HCMC). Locally owned and smaller office buildings usually have less than 25% window area. Most windows were of the fixed, non-operable single clear glass type with no exterior shading, although several employed tinted glass *(ibid)*. The use of large areas of unshaded, single-pane clear or tinted glass in office buildings may be considered a major liability for Vietnam. This practice may not only cause very high solar heat gains that lead to substantial cooling energy use, but also significant thermal and visual discomfort.

(ii) *Structure:* Walls were generally constructed of perforated clay bricks, ranging in thickness from 250-420 mm at the lower levels to 120 mm at the higher floors. None of the buildings employed wall insulation. Roofs were either flat insulated concrete deck or zinc pitched types. The built form is often rectangular with the width to length ratio varying from 1:1 to 1:3.

(iii) *Lighting:* Offices generally use fluorescent or compact fluorescent lamps (CFLs) for ambient lighting, with low levels of task lighting.

(iv) *Air-conditioning:* All foreign-owned or designed office buildings had central air conditioning, while the smaller, local office buildings generally used a number of split type packaged units.

The building survey of phase II consisted of a much more detailed on-site survey of a smaller subset of 'typical' buildings, divided into the key building categories of offices, hotels, retail, and apartment blocks, selected from amongst the preliminary phase I survey sample. Eleven buildings in Hanoi and 10 buildings in HCMC were surveyed during phase II *(ibid)*. Given the resource and time limitations of phase II, the sample was small and cannot be considered statistically representative, and therefore not amenable to rigorous statistical analysis. Nevertheless, careful consideration was given to selecting the survey sites. Therefore the survey results can yield important indicators of typical commercial building features in Vietnam, leading to a proposal for a large office building model which can be used for the simulation work to investigate the effect of a number of building design parameters on the energy performance of the model.

The study results and the proposed design tool are applicable for the two most important commercial building types at present in Hanoi and HCMC, offices and hotels. Although the simulation work is conducted only for an office building model, there is no reason for not using the same sustainable design approaches for these two different commercial building types because the study mainly deals with basic architectural design parameters which the two types have in common. The main reason an office building model is chosen for this study is that the working schedule and number of occupants is more consistent than in a hotel (The number of hotel guests and thus the working schedule depends much on factors like: annual tourist attractions, national and regional security, etc.).

4. A STUDY ON THE PREDICTED ENERGY CONSUMPTION OF A BUILDING MODEL

This study uses a dynamic thermal simulation program namely TAS (Thermal Analysis System, developed by EDSL Ltd. UK). The climate data used for Hanoi and HCMC is provided by Meteonorm, a global climatological database combined with a synthetic weather generator. The simulation program was used to conduct a quantitative parametric study analysing the impacts of design features on the energy consumption of an office building model in Hanoi and HCMC. The building model was proposed based on the survey results of the phase II of the RCAICE/EnerTeam survey, as mentioned before.

The base case large office building used for this study is a ten-storey rectangular building with a 2:1 aspect

[1] This classification is only used in this study. The first criterion (gross floor area) is the more important due to the fact that in current construction practice in Vietnam, many buildings were constructed of more than 10 storeys in a plot area of less than 500 m^2.

ratio with the longer elevations facing the N-S directions. The dimension of the building is 48m by 24m with a floor-to-floor height of 3m.

Both the building geometry and the thermal zoning for the prototypical office building have intentionally been kept simple. There are essentially two types of floor – a top floor, which includes roof loads, and a middle floor, which does not. Each floor has perimeter thermal zones, plus a single interior core zone (Figure 3 shows how the perimeter and core zones are defined, but is not a plan of the building model).

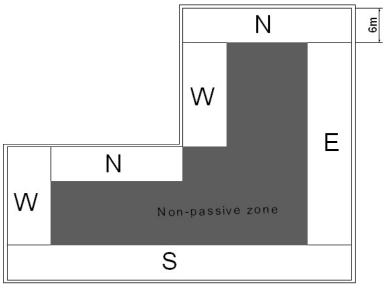

Figure 3: How the perimeter and core zones in the building model are defined

Perimeter zones can be considered as passive zones, i.e. they can be day lit and naturally ventilated and may make use of solar gains for warming up (especially in winter in Hanoi) but may also suffer overheating by excessive solar gains in summer. In this study the energy loads (cooling, dehumidification, and heating loads – if any) are predicted, assuming no natural ventilation, other than air infiltration. Core zones can be regarded as non-passive, which require to be artificially lit, ventilated, cooled, and heated (if any).

The depth of the perimeter zones should be limited to twice the ceiling height, or a default value of 6m can be used [3]. The 6m depth for perimeter zones is relevant for making use of daylight [2] and air infiltration. When defining the orientation of a perimeter zone in a corner, the best performer should always be chosen for the purpose of simplifying the calculation (for example, north in preference to east, south in preference to west, as can be seen in Figure 3). Top floor zones are potentially passive zones [3], and should be considered independently.
Parameters assumed in the base case are as follows:

Parameter	Value
(01) Site locations	Hanoi - Northern Vietnam, HCMC - Southern Vietnam
(02) Orientation:	Longer elevation facing North – South
(03) Glazing ratio	40%
(04) Wall construction	Clay brick 22cm, mortar finishing, no insulation (U-value = 1.029 W/m^2K)
(05) Roof construction	Concrete slab, built-up roofing with terracotta tile, no insulation (U-value = 1.866 W/m^2K)
(06) Window type	Clear glass, single-glazed (U-value = 6.624 W/m^2K)
(07) Air infiltration rate	0.5 ac/h (air changes per hour)
(08) External / internal solar shading	None
(09) Lighting power density	10 W/m^2
(10) Occupancy sensible gain	10 W/m^2
(11) Equipment sensible gains	20 W/m^2
(12) HVAC set points	Temperature 20˚C - 26˚C, relative humidity 60% - 70%

Table 1: Design parameters in the base case model

It should be noted that the study does not consider the impact of variations in the type of conditioning system (HVAC), as they can be regarded as *engineering parameters* and should be considered independently. As mentioned before, this study concentrates on studying *design parameters* in early design stages of the architect.

5. RESULTS OF THE PARAMETRIC STUDY

The key design parameters and variations are summarised in the following table:

Parameter	Variations
(01) Orientation:	Building long-axis facing South, South-West, West, North-West, North, North-East, East, South-East
(02) Glazing ratio	From 10% to 90%
(03) Wall insulation (polystyrene) thickness	From 0 to 75mm
(04) Roof insulation (polystyrene) thickness	From 0 to 75mm
(05) Glazing type	Single-glazed clear glass, tinted glass, double-glazed glass with blinds
(06) External / internal solar shading	Fins only, overhangs only, both fins and overhangs (fin/overhang width from 0 to 1m)
(07) Lighting power density	5, 10, 15, 20, 25, 30 W/m^2

Table 2: Design parameters and variations

The following table lists the values used in current practice and in the proposed optimised solution. The values in the optimised solution are proposed based on the availability of material and construction techniques in Vietnam and on recommendations of local architects.

Measure	Current practice	Optimised solution
Wall insulation	None (U-value = 1.029 W/m^{2}K)	25 mm Polystyrene (U-value = 0.578 W/m^{2}K)
Roof insulation	None (U-value = 1.866 W/m^{2}K)	25 mm Polystyrene (U-value = 0.896 W/m^{2}K)
Glass Type	Single-glazed clear glass (U-value = 6.624 W/m^{2}K)	Double-glazed clear glass with blinds (U-value = 2.6 W/m^{2}K)
Glazing ratio	Varying from 50-90%	40%
Lighting Power Density	15 W/m^2	10 W/m^2
External shading	None	Both overhang and fin. Depth = 1m

Table 3: Design parameters in current practice and the proposed optimised solution

The main results of the parametric study in Hanoi and HCMC are summarised in the two following graphs.

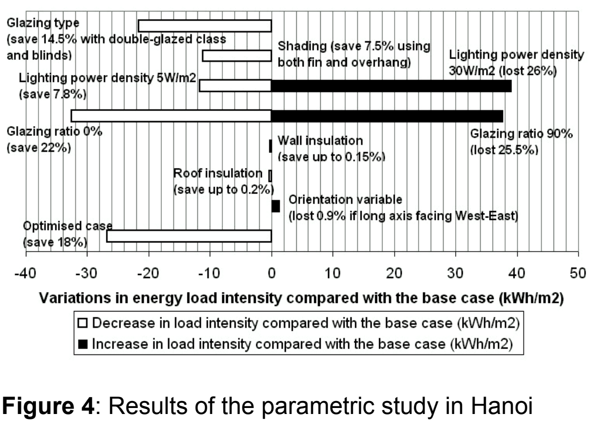

Figure 4: Results of the parametric study in Hanoi

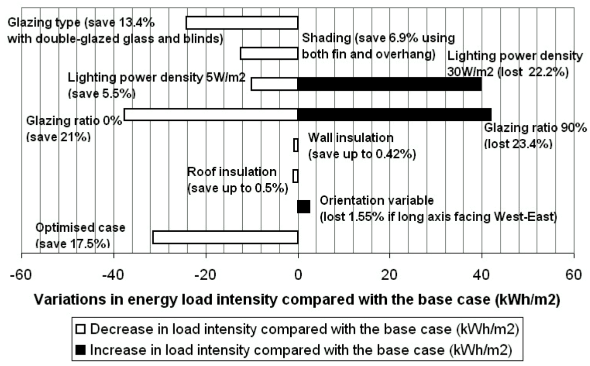

Figure 5: Results of the parametric study in HCMC

Figures 4 and 5 show that the key energy-related design features result in an energy load intensity reduction (mainly cooling and dehumidification load intensity since most air-conditioned buildings in Vietnam have almost no heating requirement as can be concluded from the above parametric analysis) for large offices of about 18% when compared with current practice. While annual energy load intensity is higher in HCMC than in Hanoi for the same building design, the *relative percent savings are about the same in both cities*.

The lighting power density is one of the most important engineering parameters that has an impact on the energy loads. In the simulation software, the lighting loads are treated as constant, not responding to variations in daylight. This could be considered a weakness of the software. However, automatic dimming, responsive to daylight, is not common in Vietnam in current practice. Besides a separate guide on lamp installation and manual control in the perimeter zones is a much more practical method to limit the artificial lighting load.

As can be seen from the above analysis, the glazing ratio is the design parameter that has the most influence on the energy loads of a typical commercial building in Vietnam. In terms of architectural design, the glazing has always received much attention from the designer since it is the most visual element on the façade. This leads to the requirement of an approach to design in which the relationship between the glazing ratio and the energy loads is given appropriate attention. This system will be represented in the next section of this paper.

6. AN ENERGY-EFFICIENT APPROACH IN THE EARLY STAGES OF DESIGN

Architects with a new commission usually start with a series of simple, small-scale sketches to determine the fundamental plan and form of the building. This is often the most exciting part of the design process, and usually the most decisive. It is important to offer a simple system for determining the energy efficiency of various plans, sections and elevations, at this sketch stage. This system needs to bridge the gap between a totally qualitative and intuitive design approach and a fully quantitative analysis by computer simulation. The objective is to help the architect understand the design implications from the very first step, so that the optimised design solution integrates technological and environmental concerns.

At this stage, two issues the architect is most often concerned with are the form of the building (plan depth, section, orientation), and the design of the facades (particularly glazing ratio, construction of window and façade). Therefore, the architect needs simplified systems (e.g. graphs and equations) that describe the influence and relative importance of these factors which have most impact on the energy consumption. In this way, the architect is left to concentrate on only these few key design variables, relating to building form and façade design. Other parameters such as the roof and the wall insulation thickness, the glazing type, etc. are set constant with the values indicated in optimised case (see Table 3). Once the less important factors are set, the system should allow the architect to investigate the effect of the major design decisions.

The tool is not a precision energy model. It uses typical energy loads (cooling and dehumidification loads) calculated for typical office buildings to test the relative performance of a number of key design options. To a large extent, the absolute values are less important than the relative variation in energy consumption produced by the design options. The trends shown by comparison between the results of various options are far more meaningful to the architect than the absolute values at the early stages of design.

7. DESCRIPTION OF THE DESIGN TOOL

The design tool, which is called SLEADT (Simplified Low-Energy Architecture Design Tool) has been developed using data obtained through detailed computer simulation analysis. It provides a set of easy-to-use graphs for Hanoi and HCMC. SLEADT is similar to the LT Method (Lighting and Thermal Method) developed by Cambridge Architectural Research Ltd [3] for UK conditions which has been proven to be useful at the early stages of design. It can be seen from Figures 6 and 7, that for each zone of the typical building model in Hanoi and HCMC, an equation is provided alongside the graph. Total energy load intensity in kWh/m^2 (cooling and dehumidification) of a perimeter zone is depicted as a function of orientation and glazing ratio (%) of the zone (window-to-wall ratio). The glazing ratio applied for the core and the top floor zones is the ratio of whole building envelope. In the equations provided, y is the total energy load intensity of a zone; x is the glazing ratio.

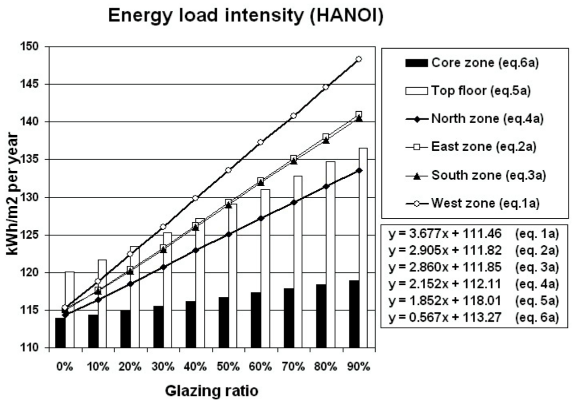

Figure 6: Energy load intensity vs. glazing ratio in a typical commercial building in Hanoi

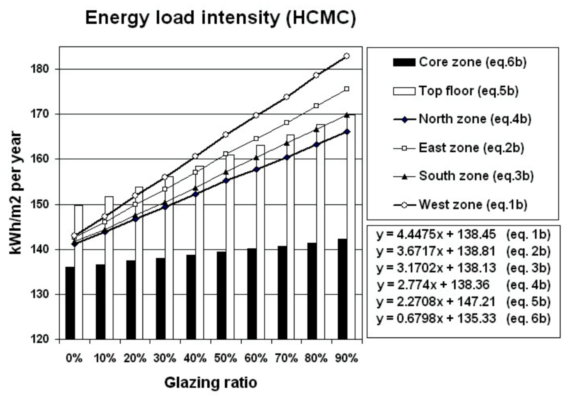

Figure 7: Energy load intensity vs. glazing ratio in a typical commercial building in HCMC

As mentioned before, in the scope of this paper the system does not describe the impact of daylight variation on the artificial lighting load.

The first stage in the use of the method is the designation of the perimeter zones by orientation, and core zones, as in Figure 3.

The zone areas are worked out and then entered into a worksheet. The full-sized worksheet is included at the end of this paper.

The following describes the use of the worksheet step by step.

Step 1: Enter the name of the building or the architectural proposal; define the climate zone of the building location (so far, there are two sets of graphs and equations available for Hanoi and for HCMC).

Step 2: Designate the perimeter zones by orientation and the core zones; specify the glazing ratio of the perimeter zones; work out the areas of perimeter zones, core zones and the top floor and enter them into the blank cells.

Step 3: Add up the calculated areas to find the total floor area and enter it into the Worksheet.

Step 4: Find the specific graph and equation for the calculation of energy loads in the appropriate perimeter zone, the top floor, and the core zone. (The set of graphs and equations for Hanoi are listed as 1a to 6a, while the set for HCMC 1b to 6b).

Step 5: Calculate the energy loads in the perimeter zones, the top floor, and the core zones; enter them into the cells provided.
Step 6: Add up the calculated loads to find the total energy loads of the building and enter it into the Worksheet.
Step 7: Specify the lighting power density of the design; use the multiplication factors provided in step 7 to calculate the net annual energy loads of the building. Note that the two sets of graphs and equations were produced with the assumption that the lighting power density is equal to 10 W/m^2. The values of multiplication factors are calculated based on the parametric study described in previous section.
Step 8: Enter the calculated net annual energy loads of the building into the appropriate cell; calculate the net annual energy load intensity of the building by dividing the net annual energy loads by the total floor area found in step 3.
Step 9: Calculate the perimeter zone ratio and enter it into the worksheet (The proportion of perimeter zone to the total building floor area is a good indicator of its potential energy performance).

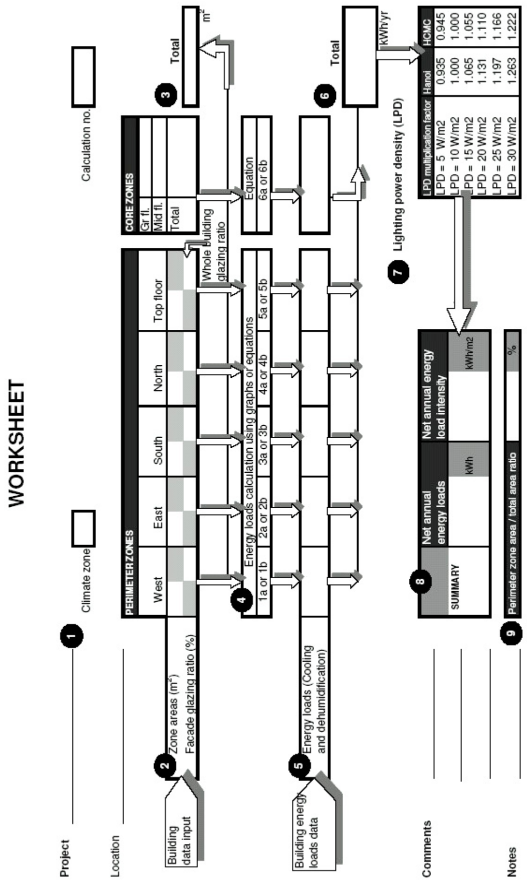

Figure 8: The SLEADT calculation worksheet

8. CONCLUSION

Assuming that the same air-conditioning system is used in each building, a typical large office building located in HCMC will use about 17% more energy than the same building located in Hanoi. The difference is mainly due to the higher cooling loads in HCMC compared with those in Hanoi. In both cities, the optimized case uses 18% less energy compared with current practice. The magnitude of the reduction is greater in HCMC than in Hanoi. However, the percentage reduction is approximately equal in both locations.

The glazing ratio has the largest impact on energy loads both in Hanoi and HCMC. Loads can be reduced by as much as 20% by using appropriate glazing ratios. It is therefore recommended that there should be requirements imposed on the details of glazing ratio and glazing type. These requirements should also consider the impact of window design on other factors such as daylight and psychological effects of windows on people.

The west perimeter zone and the top floor were found to have the highest energy loads in buildings in both cities within the common glazing ratio range (10-40%). They require a solution combining appropriate levels of roof insulation, wall insulation and external shading devices to reduce the building energy loads.

9. REFERENCES

[1] Baker, Nick, Koen Steemers. *Daylight Design of Buildings*. London: James & James (Science Publishers) Ltd, 2002
[2] ———. *Energy and Environment in Architecture – A Technical Design Guide.* London and New York: E & FN Spon, 2000
[3] ———. *The LT method 2.0 – An energy design tool for non-domestic buildings*. Cambridge: Cambridge Architectural Research Ltd, 1996
[4] Do, Tuan Viet. "An approach to sustainable architecture for office buildings in Vietnam". MSc. dissertation London: The University of London (UCL Wates House Library), 2004
[5] Edwards, Brian. (Ed). *Green Buildings Pay*. London and New York: Spon Press, 2003
[6] PA Consulting Group (with The Deringer Group and Hagler Bailly). *Survey of Commercial Buildings in Vietnam (Final Report)*. Berkeley CA: The Deringer Group Inc, 2003
[7] RCAICE and EnerTeam. *Commercial Building Surveys* (available only in CDs). Hanoi, 2002
[8] The World Bank. *Vietnam Demand-side Management and Energy Efficiency Project Report,* 2003
[9] US Department of Energy, Energy Information Administration (DoE/EIA). *International Energy Outlook 2005,* 2005
[10] ———. *Vietnam Country Analysis Brief,* 2005
[11] Vietnam Ministry of Construction. *Building Code of Vietnam, Vol.3.* Hanoi: Construction Publishing House, 1998