

BARRIERS AND SOLUTIONS TO THE USE OF BUILDING SIMULATION IN THE CZECH REPUBLIC

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ABSTRACT

This paper concerns reasons - and solutions – for the time lag in the uptake and use of building simulation in the Czech Republic relative to many other countries.

Following a brief introduction, several barriers to the use of simulation are identified. Barriers can be classified as cultural, economical or technical but there are many interactions.

The paper then concentrates on recent work and activities, which aim to reduce these barriers. A general methodology for use of modelling and simulation in Czech conditions is demonstrated in detail with a case study, which includes calibration and input data preparation. Several other case studies demonstrating the application of simulation for solving typical Czech problems are elaborated.

Incorporation of modelling and simulation in the research and education at Czech higher institutes of education is presented.

The paper finishes with elaborating activities aimed at knowledge transfer to people in practice.

INTRODUCTION

The importance of energy efficiency has grown dramatically in recent years due to global climate change commitments, regional trade and investment acts, local environmental issues, and widespread recognition of the need for sustainable development.

Energy consumption in buildings typically accounts for over 40 – 50% of the total energy consumption of Central European countries. Provision of energy services for the indoor environment produces a large amount of outdoor environment pollutants. The energy intensity (consumption in relation to GDP) in the Czech Republic is much higher than in other countries of the Organization for Economic Co-operation and Development (OECD). In the past, energy and fuel prices for consumers in the Czech Republic were very low and did not reflect the real value of energy. It is expected that energy prices in the Czech Republic will increase to world market levels within the next years.

Computer modelling and simulation has become a very powerful and important technology for assisting engineers with their non-trivial task of designing buildings and associated environmental systems such that the result is low fossil fuel consumption, good indoor conditions and minimal impact on the environment in general. Integrated modelling and simulation of buildings and systems allows engineers and other building design professionals to efficiently evaluate various energy saving strategies and environmental design options that cannot be judged adequately by more simple traditional design techniques.

Despite the rapid uptake of other information technologies in the Czech Republic, computer modelling and simulation are still seldom used in the design of new or existing buildings.

BARRIERS

Barriers to the uptake and use of building simulation in the Czech Republic can be classified under three main headings: cultural, economical and technical. Obviously there are interactions.

Cultural barriers result mainly from the fact that the various parties involved in building design are not yet aware – or convinced - of the advantages offered by computer modelling and simulation. Design practice (architects and engineers) almost exclusively uses traditional design tools. This is enforced by the Czech national standards, which present traditional tools as the sole technique to solve design problems.

In the rare cases where simulation is used, practitioners usually limit the analysis to one or two cases; i.e. analysis of the final design in case of a new building, or analysis of the current situation in case of an existing building. It appears that there is not much interest in using simulation for proposing alternative design solutions or for design optimization. More than likely this is caused by the lack of experience of practitioners with modelling and simulation. The difference between traditional design tools and the simulation approach is still not fully recognized by them.

A language barrier also handicaps the use of building simulation in practice. Until now, no comprehensive dynamic simulation program for building energy performance is available in the Czech language. Most state-of-the-art software is available only in English. This discourages many potential users. Unfortunately, the current economical situation in the Czech Republic also discourages any work on translating existing software and on new developments in the Czech language.

Other economical barriers are related to the salaries of professionals and the fees for their services. Both are very low. For example, almost every academic must generate additional income in order to establish a reasonable financial basis for living. The result is that professionals tend to take on many design or consultancy jobs. It is a competitive market, and building developers and investors expect quick results for low fees. One of the consequences is that designers will not make time available to become acquainted with modelling and simulation, even though it could be argued that using modelling and simulation may result in better, quicker and cheaper design solutions.

Many foreign investments are taking place in the Czech construction industry. Foreign investors often employ design teams – or design team members – from abroad, which use modelling and simulation much more than local designers. It may well be that this will have an important example function, and will promote the future uptake of modelling and simulation.

Examples of technical barriers are the lack of detailed input data (for example climate data and building material reference databases) and the lack of hardware. Such obstacles make the application of simulation technically quite difficult.

SOLUTIONS

The above barriers result in a relatively slow uptake and limited use of building simulation in the Czech Republic. The remainder of this paper describes a number of activities and actions, which aim to remove or reduce these barriers.

Demonstrating the Methodology

Starting from literature review (e.g. CIBSE 1998, Clarke 1998, and Hensen 1998) and incorporating own experiences, a generalized methodology for the use of modelling and simulation is formulated and elaborated in the Czech language (Dunovska 1999). The background and the methodology are discussed in detail. Application is demonstrated with a case study regarding an existing non-air-conditioned university computer classroom as shown in Figure 1. We believe that this methodology can be used as a guideline for (new) simulation users in the Czech

Republic. The methodology involves the following steps.

1. Problem definition: The considered non-air-conditioned room currently suffers from very uncomfortable conditions during summer months.

2. Aim: The aim of the study is to suggest improvements relative to the current situation which will ensure thermal comfort during working hours with minimal energy requirements. The required thermal comfort is defined as PMV in the range of -1 to 1 .

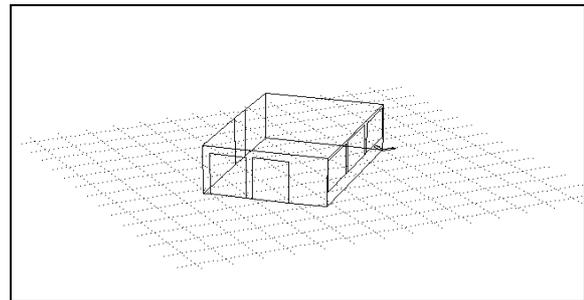


Figure 1. University computer classroom case study.

3. Reference model: A computer model of the investigated room representing the current situation was created as indicated in Figure 1. The geometry, construction elements, optical properties of glazing, internal gains, operation and ventilation have been defined. The windows have inside aluminum blinds. The classroom has 100 m^2 floor area and is equipped with 30 computers. The opening hours are from 9:00 to 18:00. In the original situation the room is ventilated constantly by $2,5 \text{ ACH}$ of external air.

The weather conditions are defined by a weather reference year for Prague (see the later section on boundary data)

4. Calibration: The reference model was calibrated by comparison the predictions with measured values. The calculated values were found to be in good agreement with experimental data. More detailed

results of the calibration are presented later (see the section on calibration).

5. Simulation: The reference model was simulated using the ESP-r modelling and simulation environment. The simulation was run for the summer period from 1st June until 31st September.

6. Analysis: Analysis of the simulation results shows that due to the high internal and external heat gains overheating will occur during most summer months in the current situation. The required thermal comfort is achieved only during 30% of the working hours.

7. Proposed improvements: Several improvements to the building construction and the HVAC system were suggested and investigated.

It was found out that the external air is cooler than the internal air during most of the when overheating occurs. Therefore increasing the ventilation can decrease the internal temperature. It is proposed to increase the ventilation to 4,5 ACH when the internal air temperature exceeds 26°C.

The simulation results also showed very high surface temperature of the aluminum blinds, which are placed on the inside of the glazing. Installing blinds between the two panes of the double-glazing will decrease the inside surface temperature of the windows and thus the mean radiant temperature in the room. This will improve the thermal comfort.

In order to ensure thermal comfort, the installation of air-conditioning will be necessary. Based on the simulation results, the supply air temperature is suggested as 26°C.

8. Improvement performance: Firstly, the thermal performance of each of the proposed improvements was modelled and evaluated separately.

It was found that increasing the ventilation from the original 2,5 ACH to 4,5 ACH would ensure thermal comfort during 42% of the working hours.

Blinds placed between the two panes of glazing would provide thermal comfort during 65% of the working hours.

Application of air-conditioning will ensure thermal comfort during 65% of working hours. 100% of working hours cannot be achieved due to the high inside surface temperature of the internal blinds.

9. Optimization: Because none of the proposed improvements on its own would not provide thermal comfort during 100% of the working hours it is necessary to combine them.

From a thermal point of view, the combination of air-conditioning with replacing the blinds seemed to be optimal. Thermal comfort is then achieved during 100% of working hours. The energy consumption of the HVAC system would be 1036 kWh.

From an energy point of view, installing blinds between the glazing panes would lower the energy consumption of the air-conditioning by 47%. Further optimization of energy consumption can be achieved by controlled night cooling using ventilation with outside air. It was found that in extremely hot conditions the increase of ventilation during night hours to 4,5 ACH results in 8% energy conservation. In extremely cold weather turning of the ventilation during night hours would save up to 55% of energy.

The results of this simulation case study demonstrate a practical solution of a concrete problem and also indicate the usefulness of simulation for parametric studies and optimization.

Increasing Trust

To encourage belief of potential simulation users it is important to indicate the accuracy of the results relative to reality. This is one of the reasons why the above model has been calibrated using experimental results.

During the course of the above case study an extensive measurement campaign was carried out. During a complete summer period internal air temperature, inlet air temperatures and resultant temperatures were measured at various locations in the investigated room.

Independently, the computer model of the room was created and simulations were performed. Hourly weather data as measured by a nearby meteorological station was used for model boundary conditions.

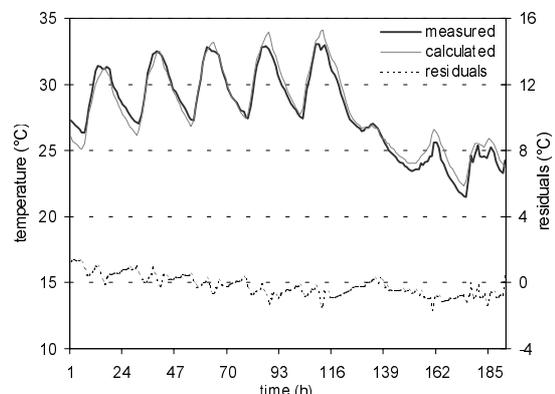


Figure 2. Measured and calculated resultant temperature and variation of the residuals.

In Figure 2, measured and predicted resultant temperature during eight days is compared. The mean residual value is 0,19°C and the variation coefficient 2,35%.

From the results it is clear that the simulation predictions show excellent agreement with the experimental data for this existing classroom.

As indicated before, this exercise has a dual function: firstly it is part of the model calibration procedure, secondly the results will be useful for convincing skeptical practitioners.

Providing Boundary Values

As indicated before, a practical barrier for the use of modelling and simulation in the Czech Republic is the lack of representative hourly weather data and the lack of property databases for typical Czech building constructions. As part of the previously mentioned work (Dunovska 1999) Czech weather data and construction properties databases have been developed.

In first instance (Dunovska 1993) a climate reference year was created based on generally available data. The available data consisted of monthly average values for the main weather variables based on long term measurements. Assuming ideal variations of each weather variable (for example a 24 hour sinusoidal variation for temperature) hourly values were generated and implemented in a weather data input file.

After establishing cooperation with meteorologists (which was not trivial!), hourly values for 5 weather variables as measured during a 14 year period were obtained. Using the Danish statistical method (Lund and Eidorff 1980) a test reference year (TRY) was generated for Prague.

At present, this TRY database is the only one containing non-synthetic Czech weather data usable for building energy simulation. A continued effort is needed to establish weather data for other locations in the Czech Republic and possibly for representing different risk levels for cooling and heating, etc.

The thermo-physical properties of typical Czech building materials and constructions were incorporated in relevant databases. It is still necessary to pay attention to the optical properties of typical and special glazing systems as used in the Czech Republic.

Demonstration By Case Studies

The applicability and value of modelling and simulation can best be demonstrated by practical case studies. Therefore several case studies were undertaken concerning typical local problems.

The first case study involves a complex analysis of strategies for comfort improvement and energy conservation in an old existing family house (built in 1933) (Dunovska 1993). A number of possible solutions to improve thermal comfort and decrease energy consumption were investigated. The effects of draught proofing, ventilation heat recovery, applying insulation and attaching a sunspace were evaluated. It was found out that application of 2 cm external insulation can save 23% of energy and provide good thermal comfort.

The second case study considers variations of heating energy consumption in individual apartments of pre-fabricated multi-family housing as widely built in the Czech Republic (Dunovska and Drkal 1996). Poorly insulated pre-fabricated apartment buildings still represent about 60% of the present housing stock in the Czech Republic. The energy consumption in these buildings is very high. The impact on energy consumption of the location of the apartment in the building, increased heating set-point, heating pattern of the adjoining apartment and excessive continuous ventilation were investigated. The results showed that the most significant influence on the heating energy consumption is due to the location of the apartment and by excessive ventilation.

The third case study analyzes the operation of the proposed air-conditioning system in a modern office building during the design stage (Dunovska and Drkal 1998). A foreign company designed the building and HVAC system which should be build in Prague. A simulation model was created with the weather conditions for Prague and incorporated the relatively complicated glazed facade with exterior glass louvers and several solar obstructions. The results show that the HVAC system proposed by designers will not provide thermal comfort under local weather conditions. Based on the results, the design team was able to suggest an alternative HVAC system.

Research in Modelling and Simulation

Several research projects using modelling and simulation have already been carried out at the Czech Technical University in Prague during the last years. Some of the results are presented earlier in this paper.

At the Czech Technical University in Prague there are now several Ph.D. projects underway in the field of building performance simulation. The results of these will be presented in due time.

To generate knowledge and gain experience in the application and further development of modelling and simulation, co-operation and participation in research projects at the international level is essential.

An example is our current participation in the European Union sponsored INCO-COPERNICUS project “Integrated Design Optimization of Building Energy Performance and Indoor Environment”. The project will be carried out in cooperation with the University of Strathclyde in Scotland, the Technical University of Denmark, the Technical University of Sofia in Bulgaria and the Silesian Technical University in Poland.

Further international research proposals are currently being prepared.

Incorporation in Education

In order to prepare the future generation of engineers it is essential that building performance modelling and simulation is integrated in the regular curriculum of higher education. At the Czech Technical University in Prague we are now at the point where there is a regular elective final year under-graduate class on “Introduction to Modelling and Simulation for Environmental Engineering”. This class involves normal lectures accompanied by many hands-on exercises and assignments, in part delivered over the Web (Hensen et al. 1998).

To better cater for the annually varying needs and wants of post-graduate students there exist also a class “Capita Selecta of Modelling and Simulation for Environmental Engineering”. In this class a number of topics related to modelling and simulation are explored in much greater depth. The class comprises lecturers, exercises and assignments.

Cooperation with the University of Strathclyde significantly contributed to solving the technical problem of lack of hardware. Due to the donation of – aged - SUN Workstations the number of students which can take the classes was dramatically increased.

These courses are open to students in mechanical engineering (environmental engineering), in civil engineering and to architecture students. Often students of different disciplines work together on particular assignments. It is a – major – side benefit that students learn to work in teams involving participants of different professions which is very valuable for later professional life.

The lectures and all the course materials are in English. Only some of the one-to-one tutorial sessions are conducted in the Czech language. Because of relative poor language skills a number of students still struggle with English terminology, writing and conversation. However, it can also be argued that a side benefit of taking these classes is to gain experience in the English language.

Despite of the problems, students are highly interested to attend these courses. Most of them will use their experience with modelling and simulation later in projects and for their final thesis work.

Knowledge Transfer

Similarly to introducing it in the education of young engineers, it is important to inform the general technical public about potential advantages of modelling and simulation.

This is one of the main aims of IBPSA–Czech Republic which was recently established. The objective here is to provide knowledge transfer among researchers and practitioners. Several papers and articles concerning modelling and simulation were already published in various Czech journals and at conferences. IBPSA-Czech Republic is, for example, organizing a international symposium and workshop on climate data and its application in engineering in late 1999. There are further plans to organize other events, which will provide information and training at different levels. IBPSA-Czech Republic is also preparing to publish a bulletin which will inform about ongoing research projects, present practical case studies, etc.

It is very important to establish better contacts with investors and practitioners. In spite of the worsening economic situation, it is very important to increase the general awareness of the advantages of using modelling and simulation by generating and showing integrated building and HVAC design for both new and existing buildings.

CONCLUSIONS

The uptake and use of building simulation in the Czech Republic lags behind relative other countries.

This is caused by a number of interacting **barriers**:

- people in practice are not sufficiently aware of the advantages offered by building simulation;
- practitioners have little experience with modelling and simulation because there are only a few practical applications in the Czech Republic;
- language problems;
- lack of detailed input data for simulation (weather and materials);
- lack of hardware.

Several **solutions**, which we believe will result in reducing these barriers, were elaborated:

- development and presentation (in Czech) of a general methodology for use of modelling and simulation;
- demonstration of the methodology in detail with a case study including calibration;

- creation of a representative hourly weather database for Prague and a typical Czech construction properties database;
- working out of practical case studies demonstrating the applicability and value of modelling and simulation for solving typical Czech problems;
- incorporation of classes on modelling and simulation in the undergraduate and postgraduate curricula at higher institutes of education in the Czech Republic;
- participation in international research projects and incorporation of modelling and simulation in Ph.D. research;
- foundation of IBPSA-Czech Republic.

There still remains a lot of work to be done to promote building simulation so that it will be generally recognized and accepted by practitioners in the Czech Republic as a powerful tool in the field of environmental engineering.

This is a very challenging task for the future.

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