Promoting Performance of Buildings through Simulation-Based Optimization: Challenges to be Faced

transcribed plenary speech of
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Thank you very much, session chair Professor KKYW Perera, members of the head table, distinguished in- vites, staff of the KDU, participants, ladies and gen- tlemen; I would like to first of all extend my sincere gratitude to the KDU for inviting me to be here at this eighth International Research Conference and make the presentation at this plenary session on the title **Promoting performance of buildings through sim- ulation based optimization: challenges faced**. Well, the title of the plenary session is to highlight on how to make use of professionalism in engineering for de- velopment. So, I hope that I will successful in com- municating brief message "how to use modeling and simulation for the development?".

The outline would be just touching upon the back- ground and issues as to indicate why building per- formance evaluation is important? Then touch upon some basic aspects in modeling and simulation and extend modeling and simulation aspect to optimiza- tion where the results of modeling and optimization can be used for the particular purpose of optimizing the building performance for different aspects, chal- lenges and issues in this context and just conclude by going through some final comments. Background and issues; just to put the things into perspective it is noted that about 30% of the worlds total energy consump- tion is for the building sector and a similar fraction for the CO_2 emissions as well. And in addition buildings last decades therefore any decision make at the design level at the inception will have an impact on the future on the energy consumption and the emissions over a longer period. Further more it is noted that people spend about 90% of their time inside buildings. And also indoor pollutant levels are noted to be sometimes 2 to 5 times than the outdoor levels. We tend to be- lieve that the always the outdoor is polluted but it is noted that indoors are 2 to 5 times and quite often polluted if not properly designed and operated.

So, looking at these key issues it is important to see that how building performance in terms of these as- pects is to be understood and optimized. Continu- ing on the background issue we also note that look- ing at the as presented by my colleague Wijepala, how the population growth is taking place, specially in the Asian region, in China and India and therefore the growth of the building sector is not going to be ex- ceptionally different from the population, and there- fore the building sector of the Asian region is going to be important, and looking at the energy consump- tion with the enhanced levels of living standards in the Asian region, with the technology transfer indus- trialization and etc. we expect the buildings to consume more and we saw that our region is consuming energy well below the world average and looking at the Asian statistics, Sri Lanka is not going to be dif- ferent from these trends, so therefore, there is a cause of concern to look into the building performance in terms of per different parameters related to buildings. If you take 2006 statistics, I believe the trend and the figures are not going to be different, 2015 how the endued fractions of energy using buildings attributed to lighting, HVAC is the heating ventilating and Air Conditioning, well in Sri Lanka, heating component is very very minute. Except the hill countries. Air Conditioning throughout 365 days for cooling and de- humidification, office equipment and cooking refriger- ation and etc. These kind of end used decomposition of energy used can be obtained for Sri Lanka. It is not going to be that much different.

You see that certain areas like HVAC the lighting are dominant. Therefore there is a potential to use infuse technology and infuse knowledge and innovation to reduce this consumption and there is a potential and from an engineering perspective there is a technolog- ical potential and knowledge that could be incorpo- rated to address these issues. Well getting to insight to modeling and simulation. Modeling is an object oriented

representation of a physical phenomena. In this context we are trying to model the building performance from different perspectives. It can be a very simple model or complex, depending on the output or the target that we are looking at from the model. It can be mathematically structured or it can be purely on experimental basis. It will map desired output depending on our aim or the target to different phenomena that we could be represented clearly identified by the inputs. It also enables investigation of different parameters in response to different inputs that are really related without going through real experimentation. Because looking at the complex nature of a building if you really want to understand the actual behavior if you wait until the building is constructed unless of course that is done at the stage of commissioning at the time of occupancy but that is rather too late. So there should be some way of engineering coming into picture where we can make the judgment at the deciding stage. It can be extended to optimize not only to understand the performance but to get the best solution in terms of what we want to optimize whether it is cost, performance whatever properly identified. It is a versatile way of decision making based on the performance cost, any other parameter that we can think of that can be incorporated.

Modeling for performance of buildings, it can be very easily put into dominantly energy modeling, modeling for comfort, modeling for the health or the air quality inside the building. As I said the quality of the air inside the building can be 2 to 5 times higher than the outdoor pollutants in terms of concentrations. Energy modeling to understand the whole building performance during a day, during a week during a month over the year, over several seasons, it is important to know. It can also tell you what are the peak loads, what time it takes place, what kind of loads that take place. If you want to and if you can focus on specific equipment and identify how it performs what kind of efficiencies? For example if you have a big piece of equipment like cooling unit, the air conditioning unit, you can focus on that and you can identify. And also it permits you to incorporate different energy efficiency measures as you can think of and make parametric analysis, make economic analysis and see what kind of energy efficiency measures look to be effective in terms of comfort. We know that inside buildings we need thermal comfort like here you need the cooling, de-humidification depending on your activity, depending on your dress etc. We need visual compel to perform our task then also acoustics audio comfort; we all sometimes need to know what kind of temperature distribution, flow distribution inside this buildings to identify how the layout should be made etc. and the third indoor air quality, what levels of concentration, specially carbon dioxide, other toxic emissions that might come out of carpets, furniture, people use lot of perfumes, different deterrent cleaning agents, etc. all this will come into the environment. This we would know, during the building operation until we are waiting at the end of the operating stage what kind of prediction that we could have in terms of before the building or when this is at the design stage so that we can take necessary steps and take actions to avoid.

So just this is the kind of environment or the landscape or the script we would look in terms of whole building simulation. At the middle we will have the simulation engine which will connect the building geometry multistory what kind of windows you have, the wall sizes, the material, then the whether condition then the type of HVAC equipment. What efficiencies you intend to, depending on the budgetary, or the finances that you have whether you can go to high end equipment or it is very appropriately selected, internal loads, number of people, equipment, lights etc. computers then the type of strategies, whether you want to control certain things, whether you want to control light depending on the outside light levels etc. and simulation specific parameters like cost and what are the certain constraints that you can look, so you can get an output from that the general block diagram would look like for a particular model, location specific geometries as you have seen in the previous diagram and more specifically assigning different zones if you want to boil down to local level performance analysis, same time going through the whole building analysis.

You can get a building information management system, you can get all these information which would be available and also the whether. So most of the cities in the world the whether data would be available. Then anybody could this free of charge from public domain sites. Well this is a typical window that you would look, I mean you would have if you use reasonably accurate, publicly available software, there are several which I wouldn't highlight down the line and you can have PDE version of the building using this you can see how the windows are placed what kind of shading would be needed

and the right side of the diagram would also estimate under different operating condi- tions in a particular day under certain whether condi- tions what would be the temperatures the roofs, the walls, the windows, all those could be predicted and also it can predict the thermal aspect, what kind of indoor environment you can have what temperature, what humidity air velocity, what kind of lighting lev- els you can have, what kind of moisture levels, what kind of concentrations, all theses can be predicted us- ing, well, your engineering knowledge and a typical modeling tool or technique. Again one degree down into the simulation tool or model, a typical case would be like combining, at the middle you have the, this is from a particular software called EnergyPlus©, there are several publicly available, just to make you under- stand, what kind of interactions that you would have to have, what kind of engineering/level of engineer- ing you would need to bring into a real building into a model enabling you to make simulations and make judgment. So, you will have, at the middle how to in- tegrate the building system parts like the zoning, the air conditioning system, then you will also have the in- terior air flow, a module and also you will have the en- velop that is the surface of the building. All can be put together and we will have this as an integrated model to perform the simulations according to the variations you would like to.

So this is a typical output that you would get, you will see that the table at the top for the twelve months of the year at the end the total for distribution of dif- ferent for cooling, for fans, for pumps used in the building, miscellaneous equipment and the lighting etc. very decomposed level you can make a further design that you have already visioned, you can get all this information and you will see, you can get graphi- cally as well for each month. Decomposed into differ- ent end use and we can also get the peak load. So the point is that, "okay you can make a judgment". If you think that the investment that you have made justified through this energy consumption or if you need more changed efficiencies in your subsystems and you can make changes and you do that. So without doing any experimentation at this stage, you can make a judg- ments relatively making comparisons within several options that you think that the design should have. And the same way, this is another way of modeling inside the building, the temperature distribution, as an example also the air velocity which will enables you to make a judgment on the thermal comfort. All these are on basic engineering understanding convert- ing into a model to get an advantage.

This is another example where the lighting levels for a different and typical types of artificial lights you use and what the level of lighting that you would ex- pect at a particular working place thereby you can make a judgment and see putting your layout inside the building whether this is adequate or you need to change and reiterate and you can do a parametric analysis. Well, we have understood that typical en- gineering understanding and the know- how can make your buildings to be simulated and understand and what kind of the output the operational parameters that you will envisage if the building is designed the way that you had planned for. But you would not know at that time how this integrated parameters can be optimized? That is one step further the objective of this slide is to show that how the building simulation tool can be integrated with the optimization tool. One step beyond the normal performance here I have in- dicated that the right typical building simulation tool that I used is Equest, and EnergyPlus is another public domain software. They are available free of charge. And the output of the simulation tool whatever the type that you select, can be coupled with an optimiza- tion tool which, for example Engenop or MATLAB©, and then you lead to an optimum solution based on what you want to optimize, whether it is on the cost element or whether it is on the indoor pollutant lev- els or whatever the parameters that you would like to. Again block diagram indicating the phase between the top part would be the optimization model of the sys- tem and the bottom part is the simulation program. Just to bring the things into perspective, so having gone through that what are the challenges in doing so, what I have highlighted, is how the engineering knowledge can be used through modeling and simu- lation and then subsequently going for optimization to bring a typical building design into the perspective that is expected by the engineer optimizing from a per- spective of cost or energy performance or whatever the parameter that you would like to, and make deci- sions at the design stage without going into operation and subsequently of course this has to be validate at some point at the initial phase of operation.

So, knowledge can be used with the experience with already done cases to see whether the assumption that you make at the modeling stage is

valid. So that is the engineering experience that you have to share for a particular case. So what are the challenges? We need high end hardware and software. Of course the com- puter memory equipment and the software, of course in most of the cases software is freely available. Ex- ceptional cases you have to purchase, but cost of the software is coming down and is not really a big issue.

Then the capital cost or etc. Computational power re- quirement, so all of these is related to hardware and software. Then more on a human resource point of view engineering perspective, competences in model- ing and optimization methodologies programming. So that is a knowledge and also a skill that is needed by an engineer and this part has to be strengthen. In- teroperability of tools combining the modeling simu- lations into optimization validation of results, you can based on anything, A software will do what you are requesting it to do. What is important is, otherwise people say garbage in and garbage out, it has to com- pare with whether your assumptions and techniques would deliver the actual results. There should be a case of validation where your output results are. Then only you can judiciously and intelligently extend these results to make decisions. What kind of decisions we could make.

Well, On the last slide I would say, building sector needs focused attention as never before due to there impact on the echo system you saw. Indoor envi- ronment impact, energy and emission impact due to use of large quantities of electricity, occupancy is be- coming alarmingly demanding for energy use com- fort, health perspectives. Everything is very compet- itive, whether it is industrial or commercial. You want to have the lowest cost of products and services. The energy cost in general is significant for therefore innovatively you bring down the energy cost, then that will be competitive advantage for you. On the other hand bringing the interior environment where the occupancy of your employees are placed, comfort and health conditions are also important for higher productivity and therefore also contributing to your competitiveness advantage. Modeling and simulation provides necessary frameworks for predicting the ob- served parameters. Whether it is energy or indoor air quality or whatever, for decision making at the design stage, without going into the operation stage. Accu- rate simulations based optimization, rather than only parametric analysis, of course parametric analysis will take you to some extend, but it is not really optimum in true mathematical and scientific sense. Optimiza- tion is a viable and an effective design tool to be cater- ing user responsive competitive value addition and policy making aspects. It is very important. We cannot make policies just based on perception it is to be based on informed facts and valid decisions. Need for neces- sary measures to meet the challenges as indicated like validation, cost and etc.

So, that is what I wanted to put into perspective as a message on the topic and thanks for the opportunity given.

Thank you