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&
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PROCEEDINGS

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Vesna Spasojević-Brkić
Mirjana Misita
Dragan D. Milanović

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Vesna Spasojević-Brkić
Mirjana Misita
Dragan D. Milanović

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PREFACE

Since the first symposium in Belgrade, Serbia nearly two decades ago, in 1996, International Symposium on Industrial Engineering - SIE has been held regularly every 3 years. It represents an opportunity for researchers in the Industrial Engineering community to review and evaluate their scientific achievements over the period since the previous SIE, share their most recent results and ideas, and discuss possibilities for new directions in research, joint experiments and observing campaigns.

The aim of the 6th International Symposium on Industrial Engineering – SIE 2015 is to contribute to a better comprehension of the role and importance of Industrial Engineering and to point out to the future trends in the field of Industrial Engineering. The Symposium is also expected to foster networking, collaboration and joint effort among the conference participants to advance the theory and practice as well as to identify major trends in Industrial Engineering today. According to these goals the Symposium addresses itself to all experts in all fields of Industrial Engineering to make their contribution to success and show capabilities achieved in the work that has been done are very welcomed. SIE 2015 provides an international forum for the dissemination and exchange of scientific information in industrial engineering fields through the large number of multidisciplinary topics.

The book brought together 80 papers and more than 220 authors from 19 countries, namely from Serbia, Germany, Portugal, Spain, France, Iran, Finland, Switzerland, Israel, Hungary, Canada, Lybia, China, FR Macedonia, Italy, United Kingdom, Taiwan, Russia and Bosnia and Herzegovina. The submitted full length manuscripts were peer-reviewed, and selected for publication by experts in their respective fields. The authors ranged from senior and renowned scientists to young researchers. Only unpublished papers were accepted and the first author is responsible for the originality of the paper. All papers are classified into seven chapters:

- Plenary Lectures,
- Risk Management,
- Human Factors,
- Production and Quality Management,
- Information Technologies,
- Engineering Management and
- Other Technologies in Industrial Engineering.

We expect that papers and discussions will contribute to better comprehension the role and importance of Industrial Engineering in this and other countries, both in domain of scientific work and everyday practice.

Our efforts in organizing would not succeed without the considerable help of the members of Scientific Program and the financial help of Ministry of Education, Science and Technological Development was greatly supportive for the success of the entire project.

At the end, the editors hope, and would like, that this book to be useful, meeting the expectation of the authors and wider readership and to incentive further scientific development and creation of new papers in the field of Industrial Engineering.

Welcome to the 6th International Symposium on Industrial Engineering – SIE 2015! We wish to all participants a pleasant stay in Belgrade and are looking forward to seeing you all together at the 7th Symposium on Industrial Engineering – SIE 2018.

Belgrade, September 2015

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SIE 2015 6th International Symposium on Industrial Engineering 24th-25th September 2015
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PREDICTING ENERGY CONSUMPTION USING CURRENT BIM SOFTWARE

Marko S. Jarić[1], Nikola J. Budimir[1], Igor Svetel[1*]
1 Innovation Center, Faculty of Mechanical Engineering, University of Belgrade, Kraljice Marije 16, 11000 Belgrade, Serbia
* corresponding author: isvetel@mas.bg.ac.rs

Abstract: The Building Information Modeling software accompanied with energy consumption prediction applications are recognized as technology that will help building industry to become more efficient. To test that claim we performed energy consumption simulation on the single building model using currently available BIM applications and software energy analysis tools. The results from the test runs are show significant variation, even within different versions of the same application. The paper discusses on the reasons for that variation and how that influences use of the BIM tools in the combination with software energy analysis tools.

Key Words: Building Information Modeling, BIM, energy analysis, ArchiCAD, Revit, simulation results comparison

INTRODUCTION

The building industry is under pressure to provide value for money. Two areas in the building design have been recognized as promising to achieve above mentioned goal: design and construction documentation without errors, and energy consumption reduction. In software arena the Building Information Modeling (BIM) software accompanied with energy consumption prediction applications are recognized as technology that provides necessary support in that endeavor.

Responding to that requirement, software companies developed plenty of applications [1]. The ArchiCAD and Revit are two main commercial BIM applications that both provide support for simulation of building energy consumption. The ArchiCAD uses built-in EcoDesigner application that enables designer to calculate energy consumption of the building directly in main BIM application. The EcoDesigner application comes in two versions, one that comes free with main ArchiCAD application that enables detailed energy consumption simulation, and extended EcoDesigner STAR version, that gives same results as free version, but enables custom result reports in accordance with requirements of different energy efficiency certification programs. The Revit application also has built-in Energy Analysis Tool, but also offers additional services like Green Building Studio (GBS) [2] – the web based application based on DOE-2 simulation engine [3]. In addition, until recently, Autodesk offered stand alone Ecotect Analysis application, that provided energy consumption simulation and offered diverse visualization tools that enabled designer to gain better understanding of building's energy efficiency.

Many third party software developers offer their solutions for energy consumption simulation. Among them the Riuska application [4] is the only one that uses IFC format to import building data, instead of gbXML. The core of the program uses the world-wide renowned DOE 2.1E simulation engine.

The applications are marketed as designer friendly tools that enable quick and accurate estimation of building's energy consumption. To test that claim we performed energy consumption simulation on the single building model using above mentioned energy analysis tools.

MODEL

The evaluation of the energy analysis simulation tools was conducted on the identical building model made in the ArchiCAD 16 BIM application.

The building model is the single floor family house with the outside walls made of blocks, plastered on the outside and with styrofoam insulation 5mm thickness. The total area is 213.1 m2 and the volume is 434.9 m3. Heating of the object is done with the boiler station. The 70% of the energy required is

realized by using natural gas, and 30% using oil. For the analysis only the lower level of the house was considered as heated with the area of 106.5 m2 and the volume of 287.6 m3 (Figure 1 and 2).

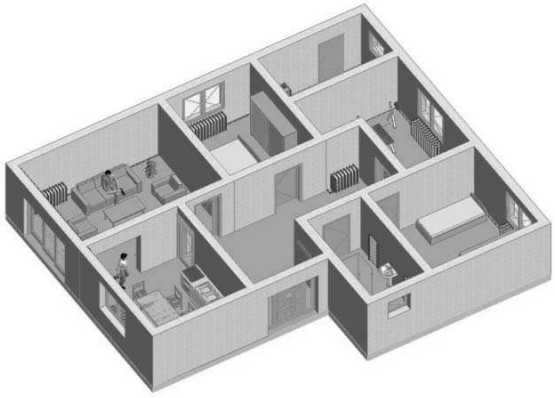

Figure 1. Axonometric view of the ground floor of the residential family house for analysis

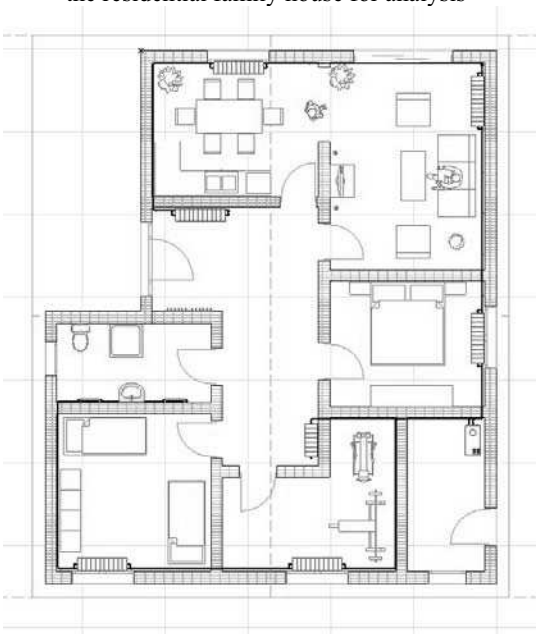

Figure 2. Ground floor of the residential family house for analysis

The tests with the EcoDesigner were performed using native ArchiCAD 16 model. Model transfer to Revit and Riuska was achieved using IFC interoperability standard format [5], and to Ecotect Analysis and GBS using gbXML file format [6]. The model modification in target applications was kept to minimum, only adjustments necessary for application to operate was performed. That way we wanted to test how applications function without detailed and specialized knowledge about each particular tool.

RESULTS

The results from the test runs are shown in Table 1 and Figure 3. It is obvious that they significantly vary, even within different versions of the same application.

Simulation software	Total energy consumption, kWh	Total annual costs, EUR
ArchiCAD 16	64215	2517
ArchiCAD 18	43576+28459	1448
Ecotect Analysis	59611	2337
Revit 2013	40564	1669
Revit 2015	51721	2129
GBS 2013	54161	2925
GBS 2015	19930	-
Riuska	45149	1779

Table 1. Obtained results

The difference in results obtained using ArchiCAD application is the result of many changes introduced in the new software version. First, since version 17, ArchiCAD introduced improved concept of building materials that accounts to more precise calculation of building element's thermal properties. Second, the notion of thermal blocks is introduced in the building simulation model to provide more accurate calculation. And last, the whole algorithm is improved to take into account new features and to provide simulation results that are closer to real conditions in the buildings. The fact that unmodified building model is used in the new software version can explain paradoxical result that shows larger energy consumption but lesser annual cost in the ArchiCAD 18.

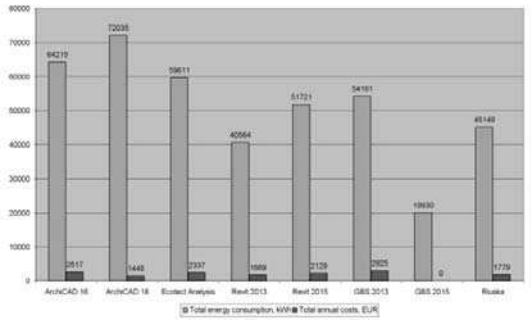

Figure 3. Chart representation of obtained results

In the case of Ecotect Analysis tool, Autodesk has decided to discontinue software development. The program was criticized because it uses not so precise energy consumption calculation algorithm that was intended for calculation by hand. On the other hand, the algorithm enabled fast calculations that, accompanied with extensive set of visualization tools, provided excellent environment for exploration on effects that particular building design can have on energy efficacy.

In the case of other Autodesk products, like built-in Energy Analysis Tool in Revit application and Green Building Studio (GBS) the information on product improvement is scarce. It is obvious that functionality of Ecotect Analysis is replaced with new functions in this software, but Autodesk also introduces new cloud based services, and it is not clear which tool provides replacement for particular functionality.

The results in the new Revit version shows consistent increase in energy consumption and annual cost that can be explained by more precise calculation engine that accounts for more parameters in the simulation. Also, it can be attributed to better interoperability between ArchiCAD and Revit applications.

The GBS 2015 exhibited most erroneous behavior. Compared to other programs the obtained result is wrongly low, and we can not obtain any result for total annual cost. The GBS application works like a kind of black box, taking gbXML file as input and providing results. When a model is imported to Revit from another application, prior to export to GBS it is necessary to establish zones in the model. The gbXML import routine in the GBS application is quite sensitive to the way zoning is accomplished, and if the file is not formatted appropriately it simply refuses import and gives no information what went wrong. So we can conclude that the new application version requires different model preparation in order to get valid results from GBS.

The result obtained with Riuska application is similar to other results. Since no information was provided on new software version we performed only one test. The main difference of Riuska is that it does not require transfer of BIM model to the simplified gbXML file format, but uses IFC model as the input file enabling designer to use full BIM model to evaluate energy consumption.

DISCUSSION

Conducted tests do not speak anything about actual precision of the application's algorithms. For that end more accurate models should be prepared. But they clearly demonstrates that simple association of the BIM tools with computer based energy consumption simulation tools does not bring about quick and easy solution for designing energy efficient buildings.

Historically, energy consumption simulation tools required three dimensional computer model of the building to generate their results. And in the era of the paper based building documentation it was requirement that hindered their use. The rise of BIM applications, that provide detailed computer based model of the building containing not only three dimensional data but also information on all physical and functional characteristics of the building components, brought about hope that merging BIM with existing energy consumption simulation tools will bring solution to the quick and easy design of energy efficient buildings. Unfortunately, as the tests show, we are still far away from that ideal.

The advances in the building model brought up by BIM applications have not been followed by the energy consumption simulation tools. They still use simplified building model as before. Since the algorithms that use simplified model have reached the level of precise prediction of the actual energy consumption, there are no reasons to use detailed model. Second, the time needed to perform calculations with simplified model is still restrictive in the case of complex models.

For that reason, it is necessary to obtain good understanding how the simplified model is created from the BIM model. In ArchiCAD and Revit applications that task is achieved using building zones. The default settings produce models that can be used to obtain energy consumption simulation but, as tests show, a precise knowledge how zones interact with building elements is necessary for accurate predictions.

Also, simple existence of the interoperability format, like gbXML, is not sufficient to establish data transfer without information loss. No rules exist to define what information is necessary to include in the gbXML file, and there is no regulatory body to guide that process. For now, in order to obtain precise results from energy consumption simulation it is necessary to have detailed knowledge what information each BIM tool includes in gbXML file, and also to know what information each simulation tool requires. The process is also complicated by the fact that each software developer introduces changes in their import and export routines in each new software version. In the absence of the regulatory body this development is often unsynchronized.

The last reason for large difference in the results obtained in the tests is the fact that each simulation tool requires characteristic information. The tools often provide default values, but obtained results are imprecise. For exact results, at this level of development, it is necessary to employ energy consumption simulation specialist who have detailed knowledge on requirements of each particular simulation tool, and also have knowledge how to obtain necessary information.

We can make question, is there any value in the ability of getting inaccurate result based on quickly generated energy models from BIM applications. While these results can not be used to make any exact prediction on future energy consumption of the building, they are still valuable aid in designing energy efficient buildings. The relative values of the results are still accurate, meaning that any increase or decrease of the results accurately shows energy efficiency of the design.

CONCLUSION

The lack of precise results, characteristic for conducted tests, is not reason to ignore link between BIM applications and the energy consumption simulation software tools. For precise results it is necessary to include professional that has good knowledge on energy consumption simulation. Also, it is necessary for building designers to know how to prepare energy model in order to achieve fruitful collaboration with energy specialist.

On other hand, designers are free to use all tools to obtain imprecise results that can be used as guides in the design process because their relative values are correct. And more the designers engage themselves in that endeavor, more they will learn about building energy efficiency and their collaboration with energy consumption simulation specialists will become more fruitful.

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