ARCHITECTURAL TECHNOLOGIES II –
INNOVATIVE METHODS, SOFTWARE AND TOOLS
BIM AND GREEN BUILDING DESIGN: EXPECTATIONS, REALITY AND PERSPECTIVES

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ABSTRACT

When first programs for building energy consumption simulation appeared in the late 1970s they were rarely used in everyday practice. Applications required 3D computer models of the building in the time when architectural practice was based on paper documentation and 2D drafting programs where considered as the state of the art technologies. With the appearance of the Building Information Modelling (BIM) applications that enable creation of the information rich 3D building models everyone expected that this technology can easily provide all data necessary for energy consumption simulation. Today, market is full of different external applications, plug-ins, and built-in functions for BIM that are advertised as solutions for the green building design. The paper gives an overview of the energy consumption simulation tools and their connection to two BIM applications – ArchiCAD and Revit and demonstrates that recent development of both technologies does not fully meet expectations. The paper indicates means to avoid overoptimistic expectations from software tools: 1) the better understanding of BIM software’s core functionality, 2) better understanding of specific information needs of each particular energy consumption simulation application, 3) knowledge about real potential of interoperability formats, and 4) awareness that energy consumption simulation applications use simplified models (building energy model - BEM), and that process of transforming BIM model to a BEM model is not straightforward and requires many specific non-standardized operations. Based on these principles designers can achieve better comprehension of the real merits that information technologies can bring to green building design. The paper concludes with the analysis of information technologies, mostly developed as part of the Semantic Web project, which can contribute to a better understanding of simulation results, and can provide more information about energy efficiency of the components that are used in BIM applications’ libraries.

Keywords: BIM, ArchiCAD, Revit, energy consumption simulation, Semantic Web

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INTRODUCTION

When first programs for building energy consumption simulation appeared in the late 1970s they were rarely used in everyday practice. Applications required 3D computer models of the building in the time when architectural practice was based on paper documentation and when 2D drafting programs where considered as the state of the art technologies. With the appearance of the Building Information Modelling (BIM) applications that enable creation of the information rich 3D models of the building everyone expected that this technology can easily provide all data necessary for energy consumption simulation. Today, market is full of different external applications, plug-ins, and built-in functions for BIM that are advertised as solutions for the green building design. The assumption that BIM will play central part in the design of sustainable and energy efficient buildings is based on the position that BIM creates models that contain all the information necessary during the design of the building, enables interoperability between applications through the use of standard data, and that data can be used and updated throughout the life cycle. This position is recently questioned because actual application’s functioning does not follow above assumptions. The paper gives an overview of the energy simulation tools and their connection to two BIM applications (ArchiCAD and Revit). The paper indicates means to avoid overoptimistic expectations: 1) the better understanding of BIM software’s core functionality, 2), better understanding of specific information needs of each particular energy consumption simulation application, 3) knowledge about real potential of interoperability formats, and 4) awareness that energy consumption simulation applications use specific simplified building energy models (BEM). Based on these principles designers can achieve better comprehension of the merits that information technologies can bring to green building design.

BIM APPLICATIONS

The ArchiCAD uses Geometry Description Language to describe all application components. It is a BASIC like programming language that defines parameters, object geometry, user interface display, behaviour, and other necessary information. The language is flexible and enables definition of any geometry, inclusion of custom parameters, and even creation of custom user interface. The designer’s experience when using ArchiCAD resembles virtual construction or mock-up making.

The Revit is an application designed to achieve effective revision update. It uses core mechanism based on relations among elements that enables quick propagation of changes from one component to all related components. The components that are part of the application library are predefined as the families. To create custom building component designer chooses family that suits her/his needs and adapts it to achieve desired results. The application’s modelling process demonstrates a kind of the “machine like” behaviour.

To accomplish similar task ArchiCAD and Revit use two different core mechanisms. Two native models significantly differ. Some functionality existing in one model completely lack in another model. That means that designer cannot expect to create models with same modelling logic with both applications, and consequently the green building design using ArchiCAD and Revit represent two diverse processes.

ENERGY CONSUMPTION SIMULATION APPLICATIONS

Today, market is full of applications that enable simulation of building’s energy consumption (Jarič et al., 2013). They can be classified in three different categories. Energy simulation engines are developed to provide accurate standardized implementation of computational algorithms. They use specialized input files and requires expert knowledge to be used. Two frequently used engines are DOE-2 and EnergyPlus. Second class of applications consists of energy simulation systems. They use energy simulation engines as the core mechanism and build user friendly
interfaces around them. That enables users to enter required data with fewer problems and to get clear interpretation of simulation results. These applications include IES-VE, eQUEST, OpenStudio, DesignBuilder, Green Building Studio, IDA ICE, RIUSKA, etc. The third class contains plug-ins and built-in simulation engines for BIM applications. They try to collect data from BIM models without much user intervention and to use them for energy simulation. Most prominent example today is EcoDesigner.

The DOE-2 is a widely used freeware building energy analysis program (Birdsall et al., 1990). The DOE-2 engine simulates the thermal behaviour of spaces in a building by calculating heat loads, such as solar gain, equipment loads, people loads, lighting loads, and air conditioning systems. The system uses fairly simplified building geometry. The user input is combined with the materials, layers and construction library to form Building Description Language (BDL) input file. The BDL processor transforms the input into a computer readable format that is later used by the four simulation modules: LOADS, SYSTEMS, PLANT and ECONOMICS, which are executed sequentially. The EnergyPlus is based on an integrated (loads and systems simulation) approach (Crawley et al., 2004), which leads to more accurate predictions of temperatures in spaces and therefore a better estimate of various resulting parameters, such as thermal comfort. The load calculations are based on AHSRAE’s heat-balanced-based approach. EnergyPlus also supports inter-zonal airflow, moisture absorption and desorption, definitions of more realistic HVAC system controls and radiant heating and cooling systems. In summary, results are more accurate and reliable than with DOE-2 for most of the simulated buildings and systems. EnergyPlus uses simple text based input files.

The IES-VE represents set of integrated analysis tools based on proprietary Apache dynamic thermal simulation engine (ApacheSim). The system is intended to provide comprehensive energy analysis in program, concept and design phases. Connection to SketchUP, VectorWorks, Revit, etc. is established using dedicated plug-ins, IFc, or gbXML files. Different modules enables designer to analyse viability of day-lighting, investigates the effectiveness of natural ventilation, and conduct either steady-state or dynamic analysis of energy consumption and indoor thermal conditions. All results are given graphically to enable better understanding but require knowledge of building physics to interpret the results with any sense. The eQUEST is a freeware building energy analysis tool which combines a building creation wizard, an energy efficiency measure wizard, and a graphical results display module with an enhanced DOE-2.2 derived building energy simulation program. The eQUEST allows users to create multiple simulations and view alternative results in side-by side graphics. The program offers energy cost estimation, daylight and lighting system control, and automatic implementation of energy efficiency measures (Rallapalli, 2010). OpenStudio is a collection of software tools that support whole building energy modelling using EnergyPlus and advanced daylight analysis using Radiance. The application includes visualization and editing of schedules, editing of loads constructions and materials, a drag and drop interface to apply resources to spaces and zones, visual HVAC and service water heating design tool, and high level results visualization. Electric lighting usage results obtained with daylighting simulation can be included in calculation. ResultsViewer module enables browsing, plotting, and comparing EnergyPlus output time series data. The DesignBuilder enables creation of the building model using custom modeller or by importing BIM models. It uses EnergyPlus engine to provide energy consumption, carbon emissions, and room comfort simulation on different time intervals. It also reports solar gains, surface temperatures and radiant exchanges. The system can be used for passive performance assessment of the building and for sizing of heating and cooling systems. The Green Building Studio (GBS) is web based application intended for whole building energy analysis and forecasting how a building consumes resources that provides estimates in tabular report form. The application reads model data only as gbXML files. Based on provided data it uses DOE-2 core engine to perform whole building energy analysis, calculate carbon footprint, consider design alternatives to improve energy efficiency, analyze qualification for LEED daylighting credit, estimate water use, and summarize natural ventilation potential and photovoltaic potentials. The application can export its results to DOE-2 and EnergyPlus file.
enabling transfer of data to other analysis tools. The IDA Indoor Climate and Energy (IDA ICE) is a tool for building simulation of energy consumption, the indoor air quality and thermal comfort. It covers a large range of phenomena, such as the integrated airflow network and thermal models, CO₂ and moisture calculation, and vertical temperature gradients. The model library of IDA ICE was written in the Neutral Model Format (NMF), a program-independent language for modelling dynamical systems by using differential algebraic equations. IDA ICE is a general-purpose simulation environment, which consists of the translator, solver, and modeller (Kalamees, 2004).

RIUSKA is a tool for the dynamic simulation of comfort and energy consumption in building services design and facilities management. It calculates inside temperatures and the heating and cooling of individual spaces, and can be used to compare and dimension HVAC systems as well as for calculating the energy consumption of whole buildings. The simulation data used by RIUSKA is saved in a special database so that it can be used for life-cycle data management. The core of the software is the DOE-2 simulation engine. The building model can be imported using IFC file format.

The EcoDesigner started as the “one click” plug-in to the ArchiCAD application enabling instant energy evaluation directly from the model. From version 16 it was branched in two parts, the built-in Energy Evaluation functionality and external EcoDesigner STAR plug-in. The new version requires all spaces in the project to be allocated to the specific zones, and from version 17 all zones need to be allocated to appropriate “thermal blocks” enabling vertical grouping of spaces. The core mechanism is the VIPCore calculation engine. Before evaluation is started information about project like location, activity, MEP system, energy type, and availability of green energy systems must be manually provided. All components of the building model can be re-evaluated using provided structural and opening lists. The built-in U-value calculator enables user to achieve a proper heat transmission coefficient values. From the version 17 it is possible to calculate solar irradiation for each individual opening in the building envelope. It takes into account environmental elements in the model, like trees and adjacent buildings, and also makes distinction between evergreen and deciduous plants when calculating solar gains during winter.Simulation results include yearly energy consumption by sources and targets, CO₂ emission, and monthly energy balance. All results are represented as charts or tables that can be saved as XLS or Pdf file.

**BIM – BEM INTEROPERABILITY**

The BIM models contain detailed information about geometry, building materials, spaces and zones in the building, their occupancy type and daily schedules. Unfortunately, these models are too detailed for the current building energy consumption simulation applications. At the time when most energy simulation algorithms were developed 3D building models were scarcity. For that reason algorithms used simplified models based on the extruded prismatic building volumes. Through the time these algorithms were refined and achieved level of high-quality prediction making. Consequently, simplified models are standard models for energy consumption analysis and coupled with other information (weather data, location data etc.) represent Building Energy Model (BEM).

To ensure coordination and seamless transition of information between AEC software applications few interoperability formats have been developed. Industry Foundation Classes (IFC) is an object oriented data model developed to attain highest level of interoperability in AEC (Liebich, et al. 2007). It defines classes necessary to represent all concepts related to the building during its lifecycle and is international standard for data exchange in whole AEC industry. The Green Building XML schema – gbXML (gbXML, 2015) is the format based on the Extensible Markup Language (XML) developed to facilitate data exchange between digital building models and the energy analysis tools. It contains specific sets of definitions and data requirements focusing on sustainability analysis. Its geometric requirements deal only with spatial volumes and
thermal zones with simple boundary surfaces. BIM application that supports gbXML must export its complex model information in the simplified form.

The process of transforming BIM model to a BEM model is not straightforward and requires many specific operations. First, it is necessary to obtain proper transformation of the BIM’s complex geometry to simple BEM geometry. It is accomplished by using spaces grouped in zones from BIM model, but requires precise definition of zones in BIM application, a task that is not supported as default BIM behaviour. Additionally, both interoperability formats defines only standard structures for data interchange, but does not define what information is necessary to include in the file. In the case of the IFC an attempt is made to standardize necessary content in the form of Model View Definitions (MVD) but BIM to BEM transfer is still not standardized, partially because IFC format does not have proper support for climate data, material data, and prefabricated components. Once the model is successfully imported to the energy consumption simulation application it is necessary to find what information is missing or is misinterpreted and to provide proper values. The information flow between BIM and BEM is unidirectional from BIM applications toward energy simulation applications. The results remain connected to the BEM model. Even if energy simulation application provides mapping of the results on the building model, that mapping is performed against simplified BEM model. The designer who wishes to design energy efficient building is forced to base her/his decisions on the interpretation of the BEM model.

Result obtained with different applications or with different version of the same application shows considerable variation (Jarić et al., 2015). The interpretation of the results requires detailed expert knowledge of particular energy simulation application. The designer does not receive any feedback from BEM model how to improve her/his design to achieve more energy efficient building. She/he cannot get any advice on improving building’s form, selecting more appropriate building components, or choosing efficient building systems. All these decisions are still based on designer’s experience and intuition.

Models are changing every year with each new version of BIM applications. This trend characteristic of software industry does not comply with the AEC industry. The duration of an AEC project can spread for several years. During that time several new software versions can appear not necessary compatible with older versions, and sometimes even some plug-ins or applications can be discontinued. This poses problem how to reuse the older models, and how to obtain again same results which were previously used to obtain certifications.

ALTERNATIVE APPLICATIONS

Some applications try to avoid problem with complex BIM models by enabling only sketching of building form and connection to energy analysis tool. Most notable example is SketchUP application that provides many energy analysis extensions. Recently, cloud based application Formit 360 enables connection to EnergyPlus engine. In order to perform this task applications make many assumptions about simple models which are often not consistent with the assumptions of the designer. In essence it is not possible to perform free object modelling and verification of its energy efficiency, but object must be modelled in accordance with the assumptions of the software producers.

SEMANTIC WEB TECHNOLOGY

The Semantic Web is created to provide universal web knowledge representation (Svetel, and Pejanović. 2010). It is based on the layered structure of representation standards. The upper layers exploit functionality of lower layers and provide greater semantic expressiveness. At the bottom level resides XML. Meaning is expressed in the next layer using Resource Description Framework (RDF), a data model that represents information about entities (resources) on the web. RDF uses triples to define that a particular thing has a property with a particular value. The
Universal Resource Identifier (URI) identifies subjects, predicates, and their values. The URI ensures that concepts are not just bare terms, but are connected to unique items on the Web. When multiple triples point to the same resource, they start to form a network of information. The next level of the semantic expressiveness is achieved with the ontology. Ontology is identified as the formal representation that defines relationships among terms. The first level of ontological functionality is achieved with the RDF Schema (RDFS). RDFS provides information about basic RDF structures by allowing declaration of classes, subclasses, property, and sub property relationships among resources. These definitions are expressed using RDF triples. The Web Ontology Language (OWL) currently provides the highest level of ontological functionality. It is a family of languages based on two semantics. OWL Lite and OWL DL are based on Description Logic semantics that guarantee completeness of reasoning. OWL Full provides maximum expressiveness and the syntactic freedom of RDF, but does not support complete or efficient reasoning. The language provides constructs like class, property, property restrictions, Boolean combinations, enumerations and instances. A wide range of services like reasoners and editing tools enable users to express and test knowledge using this formalism.

Recently, the need to extend IFC format with the Semantic Web technologies is recognised with the development of ifcOWL ontology (ifcOWL 2015). The ifcOWL enables creation of Linked Data structures about buildings by connecting IFC models with information from diverse sources (like climate data or information about building products). Similar approach is taken by HESMOS project (Guruz, et al., 2014). The project goal is to interlink BIM model with external resources with the help of a dedicated Link Model, based on the RDF. This creates a multi-model framework that will enable holistic energy efficiency simulation and lifecycle management of the building.

Another promising terrain for the application of the Semantic Web technology is finding BIM components for green building design. When searching BIM object libraries a designer can find filters based on software platforms, types of component, component brands, but there is no indication of the component's behaviour like its energy efficiency. The required information can be obtained by linking BIM libraries with product catalogues and results of energy consumption simulations.

CONCLUSIONS

The connection between BIM technologies and energy consumption simulation tools is not seamless and efficient at this moment. The designer should not assume that BIM is technology that automatically supports green building design. At the present level of development a lot of knowledge about particular BIM application and energy consumption simulation tool is necessary to define proper design workflow. The designer should monitor development of software applications as well as BIM standards to ensure validity of BIM model and obtained simulation results in prolonged time. Following these principles designer can merit from using BIM for green building design.

At the current level of development BIM technologies coupled with the energy consumption simulation tools support traditional linear design process from model toward simulation results. Since all interoperability formats are either based on XML language or have XML based variants like ifcXML the Semantic Web technology is the prime candidate for modelling a feedback flow of information. The first level of implementation would consist of linking results of the simulations to the components used to create building model. This would create knowledge about how to use the individual components for the design of energy efficient buildings. Later development could include linking information from the built buildings to the information models. This would require that all built building components are tagged using some technology (e.g. RFID) and that all spaces are equipped with monitoring equipment. That way a real building’s energy performance could be linked to the building’s information model using the Semantic Web technology. This will establish a continuum between the design phase and the building and occupancy phases by
creating a comprehensive knowledge about how particular components, IT building models and energy consumption simulation tools should be used to achieve real energy efficiency.

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NEW COMPUTATIONAL METHODS PROVIDE MEANS TO DEDUCE SEMANTIC INFORMATION FROM MEASUREMENTS, SUCH AS RANGE SCANS AND PHOTOGRAPHS OF BUILDING INTERIORS. IN THIS PAPER, WE SHOWCASE A METHOD THAT ALLOWS TO ESTIMATE ELEMENTS THAT ARE NOT DIRECTLY OBSERVABLE – DUCTS AND POWER LINES IN WALLS. FOR THIS, WE COMBINE INFORMATION, WHICH IS DEDUCED BY ALGORITHMS FROM THE RAW DATA, WITH IMPLICIT INFORMATION THAT IS PUBLICLY AVAILABLE: TECHNICAL STANDARDS THAT RESTRICT THE PLACEMENT OF POWERLINES. THESE REQUIREMENTS DEFINE PREFERRED INSTALLATION ZONES, WHICH ARE REPRESENTED BY A RULE-BASED SYSTEM IN THE PROPOSED APPROACH.


KEYWORDS: BUILDING INFORMATION MODELLING, SEMANTIC ENRICHMENT, GEOMETRIC ENRICHMENT, AS-BUILT BIM, ELECTRICAL WIRING HYPOTHESIS
INTRODUCTION

The understanding of cities and the structures and processes, that constitute them, is to an increasing amount related to data models. Building information modelling, also known as BIM (Eastman et al. 2011) provides users and owners new modes to plan, construct and follow a building throughout its lifetime. While this data is often available for new buildings, it is mostly missing for existing structures. Acquiring such a digital representation that documents the actual state of a building is also called “as-built BIM” (Volk et al. 2014). And while photographs and 3D scanning provide means to acquire geometric data of buildings, the generated surface information, obviously, does not provide an insight into any structure beneath, as the measurements stop at the first encountered surface.

However, a domain expert may be able to reason about structures beneath a surface. This work concerns itself with the formalization of such expert knowledge, or allowing a computer to replicate the experts hypothesis to some extent. The concrete domain is the determination of the layout of electrical wirings in walls, a task that is important e.g. in the context of renovation and rebuilding projects, or the detection and recycling of reusable resources in old buildings, or “Urban Mining” (Petkova and Rüppel 2014).

The presented approach was developed in the context of the DURAARK project (DURAARK, 2016), in order to enrich Building Information Models with as-built information from scans.

FORMALIZING EXPERT KNOWLEDGE

Imagine the task of a renovation project: In order to not damage any existing installations, the location of electrical lines should be identified and documented. A domain expert, e.g. from facility management, would have to walk through the building and take notes on plans where the most probable lines are. But how does the domain expert know where these lines will run beneath the surface? The reasoning is based on two key points: explicit knowledge, that is directly observable, e.g. the visible endpoints of electrical lines in a room such as sockets or switches, and implicit knowledge, e.g. the knowledge of “best practice” techniques that apply to the layout of electrical lines. This implicit knowledge may also be influenced by technical standards, e.g. the German standard (DIN 18015-3, 2007) as shown in Figure 1, which defines the arrangement of wirings in buildings. Given the explicit knowledge in a concrete situation, the expert will deduce a hypothesis using the implicit knowledge that applies to the situation.

![Figure 1: Technical standards, such as the DIN 18015-3 in Germany, propose installation zones for the preferred routing of electrical lines, which are specified by minimum and maximum distances to wall sides and elements like windows and doors. Dashed lines depict the standard placement of lines inside these zones.](image-url)
Formalizing the explicit part means to acquire observations of a building, such as point cloud scans or photographs, and detect instances of observable elements like sockets or switches e.g. by using machine learning methods. Formalizing the implicit part is not as straightforward, as it may depend on facts like method of construction or technical standards that apply to the area or at the time of building, etc.

For example, we showed a picture of the room that can be seen in Error! Reference source not found to a domain expert, which concluded a hypothesis of electrical lines as seen in the Figure.

Figure 2: Several pictures of a room (left) have been presented to an expert of facility management. Based on experience and knowledge, the expert has been able to estimate the locations of electrical lines (right).

We formalize the implicit knowledge in our method by deriving from the methodology of technical standards; electrical wires should be placed in preferred locations called installation zones, as seen in Figure 1. These zones are defined by a minimum and maximum distance from wall corners, or opening elements such as windows and doors. The knowledge is encoded as a shape grammar, a similar approach for reconstructing the structure of building facades was given by (Riemenschneider et al. 2012).

**METHOD**

The task of creating a hypothesis of the location of electrical wirings from range scans and photographs combines several techniques, an overview of the whole pipeline is shown in Figure 3:
The measurements are taken using a light detection and ranging (LiDAR) scanning device which also acquires a panoramic image that provides color information from the scanner's viewpoint. In cases in which the resolution of these panoramic images is not sufficient for later pipeline stages, an additional high-resolution panoramic image – taken from the scanner's position – has to be provided.

The pre-processing stage consists of a geometry processing step that reconstructs a coarse 3D model from the point clouds. We use the method of (Ochmann et al. 2016) to acquire a floorplan representation, together with the information of wall segments, and detected openings, such as windows and doors. Furthermore, for all wall segments an orthographic view, i.e. a 2D image representation, is created from the measurements as described in (Krispel et al. 2015b).

The next step before hypothesis generation is the digital representation of the explicit knowledge: the location of observable endpoints: sockets and switches. This is done using a computer vision pipeline that is also described in (Krispel et al. 2015b). Basically, a machine-learning-based image classification algorithm is trained with a database of pictures of sockets and switches; this classifier will detect positions of sockets and switches in the generated ortho photos.

The implicit knowledge is encoded in a generative description (Krispel et al. 2015a): a shape grammar. Applying this set of rules to the given information about a wall, its openings and detections, will create the installation zones for this wall. From these zones, a graph representing all possible connections will be created, and a final hypothesis will be extracted from this graph using a discrete optimization technique. The implicit knowledge representation is described in (Krispel et al. 2016).

Figure 3: Processing Pipeline
RESULTS AND DISCUSSION

We show results on two single room datasets and one larger dataset that consists of several rooms and discuss results and some of the observed problems.

In general, the results on the first dataset shown in Figure 4 were satisfactory. The endpoint detection performed well and the power line hypothesis corresponds to a plausible configuration for this room. There were a few false positive detections from the computer vision pipeline, i.e. the algorithm falsely reported a socket or switch when there is none, but these false positives were automatically filtered out by the pipeline, as they appeared inside an open door that was detected in the geometry processing part.
In the second dataset visually summarized in Figure 5, the result shows some weaknesses. The room is a laboratory room of CITA for virtual and augmented reality experiments with black-and-white registration targets hanging on the walls. These targets confused the endpoint detection where it wrongly hypothesised sockets or switches, although in very few cases there really are sockets placed directly under the ceiling. Furthermore, a closed door was not recognized as an opening from the scan, and therefore no zones were placed besides it. The powerline hypothesis therefore contains lots of additional power lines that connect the false positive detections to the found installation zones.

**Figure 5: Results on the second single room dataset**
A larger dataset was also acquired and processed as shown in Figure 6. In this dataset, there were a few problems in early stages of the scanning process, e.g. some parts of the panoramic images were out of focus, which results in blurry ortho photos. When getting too blurred, the computer vision pipeline fails to recognize visible endpoints and will not create a detection result (false negative). Furthermore, the geometry processing pipeline had problems to recognize the exact dimensions of windows and doors due to complex geometric configurations, which resulted in opening areas that spanned e.g. over the whole wall height, which furthermore prohibits any wire routing over this area. However, the powerline hypothesis demonstrated its ability to generate a wiring hypothesis from the data of several adjoined rooms.

CONCLUSIONS
This paper shows the results of the first complete automatic pipeline that creates a hypothesis of electrical wirings in walls for the semantic and geometric enrichment of digital building models from scanned data. The approach builds on explicit knowledge, i.e. positions of sockets and switches that have been detected in the scans, and implicit knowledge, i.e. the guidelines and technical standards that apply to a building. First results demonstrate the functionality of the pipeline on single and multiple room datasets.
We believe that such a system will be useful in practice, as it allows to integrate additional implicit knowledge. As the knowledge is represented as an extensible set of rules, it can be edited to reflect the standards that apply to a country, a time period, or the specific context of a single building.

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ARCHITECTURAL DIAGRAM OF A CITY

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ABSTRACT

Architectural diagram is a selective abstraction of a concept or an idea translated into the form of drawing. Furthermore, it provides insight into the way of thinking in and about architecture, thus creating a balance between the visual and the conceptual. The subject of the research presented in this paper is diagrams as a specific form of architectural representation and their implementation in the process of exploring and designing a city. Through the shown analysis of different diagramming practices among architects (Kevin Lynch, Christopher Alexander, Bernard Tschumi, Rem Koolhaas, CHORA, OMA), one can witness a wide variety of forms of diagrams, their functions and applications. In the contemporary world of constantly shifting relationships, designer needs a tool to understand these changes where it seems that nothing is fixed or permanent. Hitherto, this paper indicates that diagrams can be of great use to urban designers in clarifying the structure of a city, showing individual paths, complex sections and collective shared maps. The choice of diagrammatic paradigm shapes and filters the infinitive richness of a city, as a site for design intention and action. Each diagram of a city is therefore a representational schema of the designer’s own conception of the world, a microcosm of their discipline. From the aspect of city planning, diagram can serve both as an analytical tool and as a generative expression of design ideas. Analytical diagrams play an organizational role in the design, through the explanation the genesis of a city or a place, by the depiction of its contemporary conditions or relationships, and by projecting the intended future of the site through extrapolation of the design intervention. Diagrams are also generative tools - agents of investigation and revelation, forming the base on which the ideas may evolve.

Keywords: diagram, city planning, architectural representation, design process

INTRODUCTION

The contemporary city is a complex manifold where different spaces, images, structures and networks evolve, emerge and change over time. By encompassing different traces of reality, architectural diagrams are an important means for the study of the urban environment and relational forces from which the urban environment emerges. Moreover, they are valuable conceptual and empirical tools for understanding complexity in design, not only as a network-like

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In the last twenty years, architecture has accepted diagramming practice as a tool to manage complex phenomena of urban design. By these phenomena we allude on constant changes occurring in contemporary cities, as consequences of natural processes which follows a course of development that is fathomable, and consequently predictable and controllable (Kleyn and Taverne 1998). The diagram has been recognized as an important part of the design process, as “mediator between object and subject” and as a medium for researching and visualizing flows of people, traffic, goods, weather and construction processes (Hall 2010). Furthermore, a diagrammatic technique presents an opportunity to examine the social-discursive aspect of architectural practice from within (Van Berkel and Bos 1998).

As pointed by McGrath (McGrath 2010), a new array of tools which includes sensing, mapping, modelling and communication technologies may serve for creating more complex diagrams of the city, and by which the “smart” city itself can be an interactive diagram. Instead of static diagrammatic tools such as figure-ground mapping, land-use zoning or prescriptive building codes, these new tools allow the tracing of previously invisible real-time social and ecological processes. These new tools for imagining and designing urban systems are emerging now when they are the most urgently needed, as both rapid urbanisation and rapid climate change demand new ways of designing and inhabiting cities both as natural ecosystems and as information-rich signifying landscape.

DEFINITION OF THE CONCEPT OF DIAGRAM IN ARCHITECTURE

The diagrams in architecture represent the visualization of the thought process, as well as selective abstraction of a concept or an idea translated in the form of a drawing. In addition, they provide insight into the way of thinking about architecture, hence creating a balance between visual and conceptual (Dulić and Aladžić 2014). Lately, there has been renewed interest in the exploration of the potency of the diagram as an analytical tool in architecture, but likewise as an indicator of new epistemological conditions. A diagram may be defined as a “graphic design that explains rather than represents” (Lueder 2011); the term comes from the Greek word diagramma, referring to what is indicated by lines, in terms of drawing, trace and map.

The progressive use of diagrams is synchronous with the development of semiotics and theory of communication and to the first substantial computational developments in the 1950s and 1960s. The diagram is shaped as a tool for the creation, operation and representation of formal transformations and spatial relationship that assimilate the act of processing (Sperling 2004). An entire theoretical discourse has been developed around the field of architectural diagram, following the notion of diagram architecture, which was used for the first time by Japanese architect Toyo Ito in 1996, to define the new sensibility in the work of Kazuyo Sejima. As he noted, the strength and sensibility of her architectural work came from the resemblance of actual built form and reduced drawing with which it was presented (Vidler 2000). Although there are many different definitions of the way diagrams operate, one of the most important features is its ability to organize a large amount of information in a single graphic display. Given this performative characteristic, as well as the understanding that diagrams are the provisional articulation of information, some argue that diagrams offer a logical and abstract means for representing, thinking about and explaining the complex dynamic and information dense conditions we confront (Lobsinger 2001).

As stated by Allen (Allen 1998), diagrams have an explanatory function in clarifying form, structure or program to architect and others, but their most significant utility is as an abstract means of thinking about organization. In an architectural setting, organization implies both program and its distribution in place, bypassing conventional dichotomies of function versus form or form versus substance. The diagram has the ability to represent multiple functions and action
over time, so it becomes a description of potential relationships among elements. Thereby, diagram is not only an abstract model of the way things behave in the world, but also a map of possible worlds. In his seminal paper on diagrams, Somol (Somol 1998) agrees that the diagram is a function of the virtual. In that way, it serves to overcome antinomies between the real and the represented.

According to Van Berkel and Bos (Van Berkel and Bos 1998), diagrams are best understood as reductive machines for the compression of data. Same authors further point out that diagrams can also be used as proliferating machines, which is the way how architecture today interprets their use, thus transforming the diagram’s conventional significance. This specific use of diagrams has been influenced by the work of Post-structuralist thinkers, namely Gilles Deleuze who described the virtual organization of the diagram as an abstract machine; and Michel Foucault, for whom the diagram represented an expression of cultural, political and organisational effects.

The diagram evolves from the context of space, program, or history, and it does not necessarily exist in every project *a priori*. It is important to emphasize that diagrams do not map or represent existing objects or systems, but assume new organizations and indicate yet to be realized relationships. They are simplified and highly graphic, and support multiple interpretations. Diagrams are not schemas, types or formal paradigms; they are contingent descriptions of possible formal configurations, and do not resemble what they produce (Allen 1988). The difference between diagram and image lies in its instrumentalization, i.e. an image becomes a diagram when you instrumentalize it. The diagram does not simply appear, but it implies a crucial process of selection (Van Berkel 1998).

### SOME APPLICATIONS OF DIAGRAMS THROUGH THE HISTORY OF URBAN PLANNING

One of the origins of diagrammatic representation of urban space could be followed back till 17th and 18th century, to the awareness of urban space and the form of governance that this entity demands. Appearance of cartography and the discovery of the phenomenon of magnetism can be recognized as examples of materialization of space through the representation and creation of spatial transactions: networks and flows. Urban space goes beyond the opacity of the object and beyond the formal nature of the design, so it can merely be interpreted via the diagram, a graphic tool that goes past the conventions of scale, plan and object. Namely, Le Corbusier, the proponent of the plan, clearly stated in his project for the *Ville Radieuse* that the truth comes from the diagram (Aureli 2005). He claimed that diagrams are indispensable for placing theory back in its true frame.

In his book The City Shaped (1999), Spiro Kostof discussed *ideal cities*, as single-minded visions about how the world should function ideally, under the supreme direction of an individual or institution, or in accordance with some all-encompassing principle. He called those cities as *diagrammatic*, since they are the most often transposed into design in perfect geometric shapes, circles and focused squares and polygons, and they obey rigid modes of centrality – radial convergence or axial alignment (Kostof 1999). Through his analysis, Kostof highlights several cities, including *Palmanova*, ideal city of the Renaissance; *Chaux* – ideal city of Neoclassicism; and Howard’s *Garden City*, self-contained community in the late 19th century (Figure 1).

![Cities as diagrams through history](image)

*Figure 1: Cities as diagrams through history (left – Palmanova, center – Chaux, right – Garden City)*
Palmanova, the ideal city of the Renaissance, is a concentric city in a form of a star with imposed geometrical harmony. On the other hand, Chaux was designed as a full oval defined by a tree-lined ring road, which was connected to the centre by radiating avenues. Finally, the Garden City illustrated the correct principle of a city’s growth, with small circular cities surrounding a Central City and connected to it by spokes of railroad and to each other by the main road.

Furthermore, Shane distinguishes between three key urban diagram types that correspond to a specific character of a city (Shane 2010). At first, early urban diagrams concern system of emplacement, with the essential central place as a reference point. The fundamental diagram here is a circle, representing the cosmos and life cycles, with four cardinal points with lines drawn to cross in the centre, marking a new central place. These cities are called “cities of faith”, where magic ruled and oracle is required to establish a town. The following are diagrams of extension, with Rationalist systems and location theory cities. These diagrams represent the spacing and the interval between objects, a matter of great importance in the modern city with its accelerated personal mobility. At last, the diagrams of relations define cities of networks and relationships, precisely cities today. Each site in a city is defined by links or relationships to other sites, building a network. Contemporary GIS applications alter the genetic code of urban diagrams, shifting from mapping flows in space of extension to the space of relationship, mapping the space and time in between things, events, people or places (Shane 2010).

In the course of the 20th century, the evolution of the diagrams is no longer restricted to the transition from built to urban space, to the totality of the environment (Aureli 2005). The diagrams also feed back into the architecture itself thus becoming one of the most fetishized iconographic forms within the field of architecture and planning. For example, Kevin Lynch posited diagrams as a way of looking at the mental maps that citizens carried in their heads (Lynch 1960). Lynch constructed mental maps for different urban systems that described power relationships in the city, and begin to map their urban, spatial and architectural implications. By using the diagrams, architecture begins to be frozen expression of the forces: the concept of megastructure itself is nothing less than a frozen vector of the diagram. If the diagram is a vector of forces, then it is no longer possible to identify these forces in one finite urban artefact. Therefore, the urban artefact itself should resemble the form of the diagram. In this way, as the vector of forces becomes infrastructure, the city is imagined as a “plug-in system”, and it becomes diagrammatic (Aureli 2005).

Throughout the history of urban planning, the idea expressed later by Daniel Burnham, that only noble diagram can capture men’s minds, plays upon the diagrammatic as seminal (Dunster 2006). In the 20th century, Christopher Alexander questioned the nature of the diagrammatic approach in his paper “A city is not a tree”, with an augmentation of the scientific project of diagramming (Alexander 1965). In this paper, author draws on mathematical set theory to diagram selected cities, identifying tree-like networks with “artificial” cities planned in the 20th century, as opposed to semi-lattice structures observed in the social structures of existing cities (Lueder 2012). Throughout the history of architecture, one can observe a wide variety of interpretations of the architectural diagram. Application of diagrams in research and design discover the essential characteristics of multiple environments, allowing to architects, historians and theorists of architecture to visually identify and explain the specific properties of an artefact while preserving the concept of the whole.

**CONTEMPORARY DIAGRAMMATIC PRACTICES**

Along its embodiment, diagrammatic practice incorporates materiality of the construction with the immateriality of information to create a technique for actualizing the virtual. Architecture is already implicated in a number of media, and the architect constantly moves from one medium to another, transcoding from virtual to actual and vice versa. One of the key tasks of diagram architecture are constant transactions and actualizations of social, technical and urbanistic variables. A diagrammatic practice extends the horizontal, affiliative character of the diagram
directly into the field of construction itself, engendering an architecture of minimal means and maximal effects (Allen 1998). It is, however, important to distinguish a diagrammatic practice – which locates itself in the operations of transposition – from a conventional process-based work, which also foregrounds questions of representation and geometric transformation. In a diagrammatic practice, the results of the process of transposition are immediate and literal. A process-based architecture, on the other hand, usually involves an extended use of technique that is recorded in the formal complexity of the building (Allen 1998).

The ascendance of the architectural diagram occurred on one of the most important architectural and urban events of the late 20th century – the international design competition for the Parc de la Villette, Paris, 1983. This competition resulted in one of the most significant build works of the 1980s designed through, and is arguably the best and the largest building exemplar of deconstruction (Tschumi, 2010). Furthermore, the diagrammatic sensibility might be identified in contemporary architecture by the work of OMA, CHORA, MVRDV, Rem Koolhaas, Peter Eisenman and many others (Allen 1998). This architecture openly displays its constraints and is comfortable with the limitations required by the shifting field of the contemporary city. For instance, the urban projects of Rem Koolhaas and OMA move toward a new model of architecture as a form of data (Vidler 2000). The concept of the design includes verbal (Figure 1) and visual diagrams that are informative for further design stages. OMA’s analytical sensibility and the agenda of the new find in diagrams an instrument that addresses simultaneously to intellect and imagination (Deen and Garritzmann 1998). On the other hand, CHORA sees cities as dense and proliferating places, so any activity requires abstraction of conditions of change until these conditions can be manipulated, altered (Bunschoten 1998). The new urban practice which CHORA develops uses the assumption that urban form is based on dynamic behaviour and that the design urban form, to plan, to create policy, one has to understand the mechanics of this dynamic behaviour. CHORA has devised a set of methods which aim at the isolation of basic processes of change, processes which make up the ‘behaviour of a city’. An essential aspect of this isolation of basic processes is the use of diagrams (Figure 2) in order to reach a degree of abstraction in which unexpected connections can be made and in which specific configurations can be shifted across from one situation to another. Diagrams become tools of modelling or simulation of situations in motion (Bunschoten 1998).

Diagrammatic practice provides a theoretical account for dealing with large-scale projects and complex decision-making processes. Nevertheless, the implementation of diagrams needs to be vigilant, because they create the illusion of simplicity and clarity or urban tissue, which is not the case in reality.

*Figure 1: OMA’s verbal diagram for Yokohama Masterplan, 1991.*

*Figure 2: CHORA’s diagram for Carlsberg urban incubator, 2007.*
CONCLUSIONS

Architectural diagrams are tools developed by designers to help them understand the contemporary city of constantly shifting relationships, where nothing appears permanent or fixed. Diagrams of the city may be both magical and scientific, or a strange hybrid combination of these two, like urban design guidelines that manipulate the city image to create a desirable, marketable scenography. This paper has shown that diagrams can be of great use to urban designers in clarifying the structure of the city, its genetic code in small patches and its dynamics between patches. They can show individual paths, complex sections and collective shared maps. At the same time, they have their limitations like any analytical device. Diagrams are inevitably reductive and simplistic. The life of the city and local conditions easily escape their net. Diagrams help us see the city, but at the same time can blind us to its real complexity and fluidity.

We can conclude that the power of the diagram is its ability to evoke the reshaping of an entire situation with one simple gesture. Thus, the most problematic aspect of the diagram is its capacity to subsume something that is irreducible to any representation. This is even more evident in the recent use of diagrams, where the iconographic persuasion, or better, its graphic décor, becomes the main essence of its content. Therefore, there is a paradox in our discipline: On the one hand, architectural form is less and less important; on the other, architectural thinking – the kind of autonomous, creative, and nihilistic architectural thinking that reduces things to always changing icons and signs, to nothing – is able to reconstruct a representation of the world, updating it beyond its immanent possibilities. This pervasive iconographic power of diagrams as the representation and updating of everything beyond the being of things is ultimately summarized by Rem Koolhaas, who claims that architecture liberated from the obligation to construct can become, in fact, the diagram of everything (Aureli 2005; Koolhaas 2004).

REFERENCES


DIGITALTOOLS-BASED PERFORMANCE EVALUATION OF THE ADAPTIVE BUILDING ENVELOP IN THE EARLY PHASE OF DESIGN

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ABSTRACT

Amelioration of indoor comfort for the building occupants, reduction in energy consumption and carbon dioxide emissions can be achieved with application an adaptive building envelope in new and old buildings.

Nowadays, there is a lack of methods for predicting and evaluating the performance of the adaptive building envelop at component and whole building scale. Also there is a need for guidance on how to model the adaptive envelope system and how to simulate one in a suitable way.

The aim of the paper is to review the existing literature and projects on methods, techniques and strategies for the adaptive envelope performance assessment in the early phase of the design (in scope Computer-Aided Architectural Design - CAAD).

Authors are currently carrying out a classification, critical and comparative analysis of the existing simulation and modelling approaches for the adaptive façade with focus on the design of exterior shading systems. After the aforementioned analysis they have implemented workflow proposed on a case study.

The case study is discussed to show how the method proposed and based on digital tools can be applied. Numerical simulation is conducted to predict and to evaluate performance and possible energy reduction application the adaptive exterior shading system. In this case geometry and material characteristics of shade systems are investigated in relation to daylight and light performance of indoor space.

Keywords: adaptive envelope, digital tools, early phase of design, performance assessment, shading systems.

INTRODUCTION

Climate changes and growing sensitivity toward energy consumption have inspired designers with new challenges regarding the design of the environment. In the construction industry the...
energy consumption is the highest and innovative solutions, new and different design approaches need to conserve energy. The building envelope is one of the most important parts of building that contributes to energy efficiency of building and thus low environmental impact. Design of the building envelope influences on the consumption of energy and indoor comfort quality. In this sense, adaptive envelopes can provide extreme benefits.

The building envelope performance directly influences cooling and lighting energy consumption. According to ASHRAE Fundamentals Handbook (2009) one of the most important ways to reduce overheating of interior spaces and reduce energy required for cooling is to block direct solar radiation before it reaches the glass. Olgyay states that "the most sensitive single element of the structure is the window area. Its positioning for winter and solar control during summer produces the largest effect on heat flow balance" (Olgyay, 1963). Also quality of the fenestration, frame and glass, may influence the reduction of solar heat gains. When designing adaptive building envelopes, one of the main challenges is designing the outer layer of the envelope – shades, which in extreme cases should prevent overheating the interior space, and at the same time enable sufficient penetration of daylight inside the object.

Modern scientific and technical achievements offered new possibilities for designing shading devices. The role of the adaptive envelop is to control energy flows between the interior and exterior of the building, and thus with adaptive envelope it is possible to managed the energy consumption for cooling, heating, lighting and ventilation of indoor space. For the façade, design is believed to be the crucial in achieving zero energy buildings or an overall reduction in energy consumption. Also, it is necessary that the architectural, structural and building physics requirements are integrated in the design of the adaptive facade system. Shades can be designed as movable objects that move according to the Sun. Other possibility is designing shades that are immovable and whose shape and position are optimized based on the geometry of the Sun on the annual level. Both approaches offer new dynamism of forms and shapes.

The study offers some important insights on relation between the performance evaluation, the early phase of design, and the adaptive building envelope. But the paper does not engage with practical constraints. The overall structure of the paper takes the form of three sections. The first one begins by laying out the importance of the early phase of design. The second section considers the adaptive building envelope and the third section discusses the performance evaluation based on digital tools including presentation of the case studies. Throughout this paper, the term digital tools will refer to small or big programs, plug-ins, add-ons or scripts which are based on computational logic and on algorithmic procedures.

THE EARLY PHASE OF DESIGN

It is often practice in designing process to consider the building physics and check the energy performance of project when the designing process is nearly the end and project solution is already defined. In many cases, completed project does not fulfill the requirements of building physics and then it is necessary to create many modifications or corrections of the project or in many cases start all over again. The alternative is to consider the building physics and to assess the energy performance from the very beginning of the designing process and so searching for successful solution. But mostly, tools and calculating methodologies are designed to be used on developed solutions. Working procedures, in relation to early designing stage and using of digital tools, are undefined and in phase of developing. Petersen Steffen et al. (2010) in the article *Method and simulation program informed decisions in the early stages of building design* state that today is needed to develop practical design technique to reach high energy performance building, especially in early phase of design, because advice design tools are not well developed and limited to evaluate energy performance of building by designer. Some reasons are: the need to find, develop, check and then compare the many possible solutions in a short time period, but to do so requires accurate and valid information so that architects can make the right decisions.
Lack of working procedure for designing dynamic shading system, especially when choosing and using digital tools is noted.

THE ADAPTIVE BUILDING ENVELOPE

During the past half century a number of research papers, books and projects have been published suggesting different ideas about the building ability to adopt changeable circumstances. In the book Soft Architecture Machines, Negroponte Nicolaus (1975) states that buildings need to adapt to environmental conditions and human demands and needs. Some authors have mainly been interested in the adaptive architecture concerning the interactivity regarding to environment’s and users’ changes, like John Frazer (Frazer, 1995), Mike Weinstock (Hensel et al., 2013), Cedric Price (Mathews, 2006) and Gordon Pask (Pickering, 2010). Michaela Turrin et al. (2011) in Parametric modeling and optimization for adaptive architecture have noted: "... adaptive architecture is based on the interdependence between the varying needs/demands and the capacity of a building to satisfy them in a changing environment". Jan Knippers and Speck Thomas (2012) in the article "Design and construction principles in nature and architecture" use the term convertible structure to define an adaptive building envelope that is able to change its geometry. This paper presents the adaptive behavior as process in which the building envelope transforms from one form to another one and has ability to self-adjust to changeable user's needs and demands and to changeable situations in environment.

Designing the shading systems

To date, several studies have examined the association between workflow approaches and the design of louvers. In the book Sun, Wind & Light: Architectural Design Strategies, Mark DeKay et al. (2014) provide us with the strategies for design external shading devices. Olgyay Victor (1963) presents approach to analytical design of shading systems in the book Design with climate: bioclimatic approach to architectural regionalism. Mazria Edward in book The Passive Solar Energy Book (1979) further developed aforementioned Olgyay’s graphic method for shading systems design. From then until now, the approach of Mazria and Olgyay to design and devise louvers has been improved and advanced.

In Methods and approaches in designing shading systems ware the same for a long period but in the past two decades the breakthrough has been made in this area. In this period many authors developed different methods based on computation technologies. Among the many methods for designing louvers, a method called Eco thermal method, Eco Degree Day method or Shaderade method should be noted. Sargent et al. (2011) presented the use of this method in designing shading system and noted that it enabled achievement of the best results and the greatest energy savings. This method is incorporated in DIVA, and used in case study analysis.

THE PERFORMANCE EVALUATION

The designers/architects need the knowledge about techniques and strategies for the use of digital tools to assess specific performances of adaptive envelope in the early phase of design. In this case the strategies means a set of decisions regarding the way in which architects/designers can perform the process of designing adaptive building envelopes on the basis of digital tools. This particularly applies to the collection of relevant information and processing and inclusion of this information in the conceptual design in accordance with the requirements of the design. Proposed design workflow is divided in a several steps: defining working criteria; making parametrical models; simulation and analyzing; measuring and assessing performance; preparing data for manufacturing and fabrication; also process optimization can be considered; physical simulation and testing prototypes.
Digital-tools

In the past several years, many digital tools were developed and many researches were conducted. In this paper, the digital tools that architects use to design, check and test the exterior shading system of the building envelope are presented. End-user development (EUD) is based on visual programming tools such as RhinoScript for Rhino, MEL for Maya, DesignScript for Revit etc. With these tools the end user automates and customizes sub tasks during design process. A visual interface of these tools help architects/designers to end-user development (EUD) without high level programming knowledge. The main aim of this script is to give opportunities for repetition and automation during design process. Tools include knowledge of building physics which is the basis for designing that should contribute to preservation of the environment and user’s wellbeing. Grasshopper (visual programming plug-in for RhinoCeroes) within RhinoCeros platform is used in design process to parametrically make geometry of shading system, envelope and building. These tools aid the architect/designer to use the least necessary geometry to cover the opening on the building envelope during a certain period of the day. In other words, using these tools designers can determine the geometry of the shades in relation to geometry of the movement of the Sun for a specific location.

Figure 1: Diagram of relation between digital tools within Rhinoceros platform that are used in design process of an adaptive envelope.

In the past few years, digital tools for Rhinoceros platform have been developed to simulate energy flows in an architectural design at different levels – from component level to urban contexts. This tools (Honybee, Ladybug, DIVA, geco, Archisim) link the working environment Rhino with EnergyPlus when calculating thermal properties, and Daysim, as part of Radiance, when calculating daylight in interior spaces analysis (Figure 2). For example, the tool DIVA is used for performance design. Using this tool it is possible to check the lighting and thermal properties of the model, within Rhinoceros platform.
The case study office building in New Belgrade, Serbia

The following section will discuss in detail above mentioned workflow for the early phase of design (Figure 2). Here is presented basic information about the design of the exterior shading system for the office building located in New Belgrade, Serbia. Here is offered the method for assessing daylight performance in the effort to reduce energy consumption and to achieve visual comfort. Firstly, weather data for Belgrade city are considered. Then a typical office story has been selected to be the model for testing. The parametrically made model of the office unit and the shading systems is created. Subsequently is made input for simulation to test design solutions of shading systems.

Figure 2: Diagram workflow of the performance evaluation for the visual comfort (1 Input parameters, 2 calculation/simulation, 3 assessment and evaluation, 4 making decisions, 5 implementation/redesigning).

The office building is located in New Belgrade at latitude 44° 48'N and longitude 20° 27'E. The orientation of the typical office unit is the south. The building has the facade without the exterior shading system; the glass transparency and the interior blinds are used to control thermal and daylight performance in the building. This case study based on the parametric geometry, is used to investigate the geometrical characteristics of exterior shading systems and their influence on thermal and cooling loads, and on the daylight performance in the interior office space.

The Figure 3 shows parametric modeling that was used to define geometry of typical story and exterior shades. Several steps were conducted: division of office building on stories and choosing of a typical one. At the beginning, the selected story was separated from the entire building, and then measuring and testing were performed using simulations. Dimensions, such as story height, front width, and walls, openings and floors ratio, were parametrically entered so that they could be changed by changing the values of these parameters. Then the defined geometry was divided into components, for example: floor, ceiling, walls, roof, doors and windows, so that the specified geometry could be recognized as a totality in digital tools EnergyPlus and Radiance.
Simulation and verification of daylight performance is done using the next metrics: annual heating, annual cooling, artificial lighting, DA$_{500}$lux and UD$_{0.0000}$lux. Standards for daylighting were considered according to IESNA Lighting Handbook (Quality of the Visual Environment) and the used value of minimum luminance for working space in office building was 500lx. This value is expressed as a percentage and represents the time during the year when workspace is being used and minimum illuminance requirements are met, using only day/natural light. At beginning of the simulation process, the input values are entered for the location in Belgrade. Then, a characteristic material was added to each layer which contains geometry. This is necessary in order for Radiance to be able to identify which components have which reflection, absorption or transparency, so that the simulation of lights arrangement could be performed. Then positions of nods - sensors were defined, setting the plane and points, on which the illuminance was measured.

CONCLUSIONS

This paper is presenting traditional and contemporary methods of designing shading systems. This paper explains the workflow that could help designers/engineers to make effective and informed decisions in the early phase of the shading system design. This is presented as a simplified method for a predicting visual and thermal performance of interior space considering a design of a shading system for office building in the early phase of design. Shading system is defined parametrically and then optimized to reduce energy for lighting and to achieve visual comfort of users. We believe our work could be a starting point for future investigation. One area of future work will be to represent: relationships between models and tools explicitly, in the detailed phase of design. This work should benefit greatly by using data on Building Information Modelling (BIM) and Building Energy Modelling (BEM).

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INCREASING QUALITY OF PLACE BY USER’S VALUE ORIENTATION

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ABSTRACT

Better understanding of the city dynamics leads to smart urban growth. The ambition of this paper is to expose the facility management role toward society needs and industry development. Hand in hand, society (people and organization) and building (space and infrastructure) have to develop together in a way to create better value for the users. The main purpose is to get a usable model to gather analyse data from existing housing areas as a base for developing smart urban growth to meet changing social needs. Combination of data mapping and value contribution mind should turn out to be effective tools for gathering and analysing a lot of information. The way of classify information gives opportunity to aggregate data and with new technology to visualize, results to obtain effective way of communicate complex information.

According with an international trend to strengthen integrated solutions in the early stages, as the basis for the project’s value over time, and in the context of value management to coordinate the various actors’ values before designing the project, the research looks at the needs and content that ensure the requirements for the owner and user’s added value. The results from the research, running in Norway, Germany and Slovenia, show that with value principals the attractiveness and stickiness of areas in competing European regions can increase.

Keywords: urban growth, housing stock, user’s perspective, value orientation

INTRODUCTION

Real estate situation in several European countries globally exposes the need for changing the housing strategies in accordance with the housing market volatility and people needs. Better understanding of migration and logistics flows, related to city dynamics and associated risks to enable good facility management and forecasting of supply and demand for service and products in cities, has to be key element of housing strategies.
The fundamental questions of environmental studies are: how are different environments linked to social behavior, what are the interactions between the environment and social behavior and, how do they adapt to the affected changes (Rus, 1997). Interaction models between humans and the environment apply to analyses of social variables with respect to the influences of physical factors and to the analyses of variables in the physical and designed environment. We are accustomed to cognitive and decision making models of interaction between man and the environment. Cognitive interaction models mainly deal with issues, such as the relationship between environmental characteristics and personality, how do differences in cognitive perception and categorization of the environment by representatives of different social and cultural groups manifest themselves in their social and spatial behavior, attitudes and stereotypes about the physical environment and features of social representation of various macro-objects and macro-events.

Spatial behaviour and real estate market changes are linked to the concepts of values from different perspectives, as ex. from economic and psychological one (price for example is a value expressed as money, but psychologically value is interpreted as a preferred concept of desire). Concepts of values are mutually tightly intertwined. From psychological perspective we can define that ‘every environment surrounding ‘humanity’ has certain features, characteristics that need special attention, simply because they are very important for humans, their life, survival, living, leisure and work’ (Temeljotov & Rus, 2004). All of these ‘directed’ attentions of the inhabitant can be evaluated, both in the sense of satisfying their personal needs, as well as economic indicators.

The principles of property evaluation are distinguished into subjective and objective, yet intertwined categories: principles that are derived from user’s perceptions and those that are linked to the market environment. Value can be attributed to property at any given moment of it lifecycle: planning, initiation (birth), growth, renewal, decay and demise. Planning and development are important elements of this process, similarly as the past, present and future development of the entire micro- and macro-environment.

Many researches compares the changes of value perspectives in Facilities Management (FM) through the years. The different research perspectives provide, in combination, a holistic view by integration of an external market based view (aimed output) and the internal resource based view (input from FM and RE). Jensen &all (2014) write a list of emphasis for added value of FM, including at the beginning the focus on strategic aspect of FM towards the business impacts and effects. Coenen at all (2014) state that the demand side perspective of value in FM in terms of market segments, which group buyers with corresponding behaviour, differ groups by ‘customer’ to three, as ‘client’ – organization that procures facility services, ‘customer’ – organizational unit which specify and order delivery or services and ‘end user’ – person receiving facility services. For them key stakeholders are no longer seen as separate but rather as an integrated economic system to co-create value in FM. Through researches (Jensen at all, 2012, Houvila at all, 2012, Sarasoa at all, 2012) the value elements are found, which assure the increasing of value contribution to attractiveness and stickiness of the built environment, from user’s and business perspective. From the user perspective, they are connected with better living condition, like: sustainability, adaptability, reliability, perceived value for benefits, and for business the focus is in the harmonization of the resources and provisions.

By strategic level of FM it is possible to collect, organize, visualize and communicate data as means for strategic planning and budgeting (Bjorberg at all, 2012). Real estate and facility management orientation should be more focused in user’s needs and value creation perspective. User’s value approach has to take into consideration the multi-directional character of urban environment, including socio-psychological characteristics of different group of population.

By sustainable oriented FM it is possible to establish a positive balance between immigration and migration of an individual, which allows gaining the social capital and estate capital, as called
(Musterd, Goetluk, 2005) ‘the situation of dynamic balance’. On the basis of individual needs and quality of the built environment the state in the urbanisation area can be reported as attractor and/or sticker for an individual or groups.

**Research**

The supply of housing units on the market can be categorized on the way of categorization according to extended care dependency scale, facility management excellence and availability of logistic services. A tool for strategic urban portfolio analysis could facilitate visualization of various age cohorts in defined housing markets. Four-degree neighbourhood and urban development scale can be used and reported to attract the potential developers and buyers of property in the analysed housing area. Such information system which provide timely information regarding built environment and services including availability (costs) in competing European regions can increase or decrease attractiveness and stickiness of these areas according to the age groups and/or functional capacity of potential residents.

This tool could facilitate mapping, planning and visualization of availability and needs of various age cohorts in an analysed geographical area. Facility management, facility services, health services, social services, etc. could be better managed and reported by analysis of particular geographical areas. Service innovation and service design are two approaches for further development of Facility Management and Facility Services to maintain the citizens’ wellbeing and independent living. The results from the analysis of particular geographical areas could serve as the starting point for development of new tools and methods for development and visualisation of improved Facility Management and new facility services tailored to the inhabitants’ needs.

The research is divided in different phases to follow the long life perspective of keeping value, adaptable for future needs in social and individual way. With a good interactive decision tool, we also want to get LCC building/neighbourhood oriented competent players.

**Different tools**

The Nordic SURE-project - Sustainable Refurbishment of Buildings, (Almås et al, SBC 2013) investigated different methods and tools to assess buildings and building portfolio. Based on a list of criteria, such a method should 1) give indication of potential of the building to be developed, 2) be used in preliminary phase as input to decision, 3) is intended to serve as a tool to make recommendations, 4) collecting data should be simple and 5) it should be user friendly and visualize the results. MultiMap, LCA, BREEAM In-Use, SURE, SIA (Sustainable Impact Assessment) and LCC (Life Cycle Costs) where evaluated.

![Figure 1. Holistic Analysis Model for strategic development of building portfolios (Larssen, 2011)](image-url)
All of these methods and tools have different advantages. But for the purpose assessing building portfolios MultiMap combined with LCC should be considered. MultiMap as a method is based on a holistic approach shown in figure 1 to assess the GAP between today status of performance and future needs or demands.

An adapted version for the purpose of smart urban growth shall be developed as shown in figure 2, where social and environmental aspects are implemented. These aspects, as two of the legs in Sustainability, are essential regarding well-being for individuals. By using the tool, all necessary information will be the base for spinoff to create analysis for future situation.

The assessment method is based on two main approaches; 1) data input provided by FM-personnel with good knowledge of the actual building portfolio (space and infrastructure) with some assistance from persons with knowledge about core business of the portfolio (people and organisation), 2) assessments of interviews of users of the portfolio (social and environmental aspects including economy). Collecting information for building portfolio gives a lot of data. For communication purpose of all data Onuma Planning System provides possibility for visualising in 3D pictures (figure 3).

![Figure 2. Model for developing smart urban growth](image)

![Figure 3. Presentation of data using Google Earth and Onuma Planning System](image)
Basic costs will be rent of space. This should be a “cost covering rent” based on annuity of net present costs (NPC) seen in a defined period as shown in figure 4. Anticipated costs over this period, such as yearly operating costs like energy, household insurance, cleaning, and public dues, and periodic costs like preventive maintenance, replacements and minor upgrading, should be taken down to NPC. NPC put back as an annuity will then be the calculated rent as a minimum to meet the anticipated costs.

**Research project**

The newly started research project “OSCAR – Value for User and Owner of Buildings”, with the main intention to develop competences, methods and analysis tools for optimizing building design in a way to contribute to value creation for owner and end-user throughout its life time, will take smart urban growth as a case.

The project takes into consideration a clear connection between the design and operation of the buildings and values for the owners and users. To achieve value creation processes, it is necessary to have competent actors who have good tools for decision and communication through projects and processes. Life Cycle Aspect is essential as an input in Early Design Phase, and the processes through the following phases have to assure its inclusion in a way that value creation is complied with the user phase. The research findings in Oscar project are a result of cooperation with 17 project partners from three countries from academic, private and public sector from all stakeholder groups. It is presented how it is possible to achieve more efficient buildings by collaboration of stakeholders from the early beginning with the same goal to maximize value for owner and user over building’s life time. In accordance with findings from literature review and purpose of the project, the relevant stakeholder groups for Oscar project are: owners, users, planners/designers, consultants and contractors, FM providers and society.

Project contains three project groups (figure 5) and phases, with a goal to: 1/ to define the knowledge how to contribute to value creation in user phase as input in Early Design Phase (focus on characteristics which contribute on value creation); 2/ to define execution models and processes which contribute to value creation, and 3/ to design methods and tools (focus on cost benefit evaluation simulation model).

![Figure 5. Value contribution model](image-url)
From literature review about value aspect, it was concluded to use OSCAR definitions as:

- Value creation: process needed to achieve value.
- Added value: innovation and possibilities throughout the project process which can increase value outcome.

Within the first phase of the project, a list of characteristics and means are found from literature review, which are important for the value creation. (Table 1, Table 2).

### Table 1. Characteristics for value creation

<table>
<thead>
<tr>
<th>Project group</th>
<th>Subgroups</th>
<th>Characteristics or Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 1 – Characteristics which contribute to value creation</td>
<td>Economic (MOME, core business cost, investment cost, economic value)</td>
<td>Optimum FM organization, maintenance plan (predictability), outsourcing, transparency of costs, cost of ownership, running/operational cost, cleaning cost, space efficiency cost, rental cost, interaction of costs (best solutions not lowest costs), project cost, cost reduction, green accounting, potential income, strong brand, market value, payback time, profitability for the core business, productivity in construction phase, long term commitment partnership</td>
</tr>
<tr>
<td></td>
<td>Social (People and organization)</td>
<td>Architectural value, satisfaction, indoor climate, comfort, individual control of conditions, aesthetic value, open view, layout (open /cell space), enough space, orientation, cleanliness, logistic service support, organizational value, social responsibility, location characteristics, historic value, usability (efficient workplace), accessibility, safety, security,</td>
</tr>
<tr>
<td></td>
<td>Environmental</td>
<td>Renewable energy, energy efficiency, recycling and reuse of materials, waste management, minimize contamination, environmental friendly products, life time materials, green roofs</td>
</tr>
<tr>
<td></td>
<td>Physical (Space and Infrastructure)</td>
<td>Technical condition, space distribution / logistic for core business, quality materials, construction quality, architectural solutions, life cycle design, environmental solutions, flexibility possibilities, elasticity possibilities, generality possibilities, designed for disabled persons, sufficient infrastructure, innovative solutions</td>
</tr>
</tbody>
</table>

Based on the questionnaire with over 600 respondents from Norway regarding value creation for owner and user, it was found that from economy aspects, the most important is investment costs (88 %) and the lowest is cost effective service aspects (57 %). From environmental aspects indoor climate (comfort) was evaluated as the most important (80%) and lowest recycling materials (70%). For social aspect user involvement is evaluated as the most important (70 %), and space for physical activities as the lowest (55 %). From physical aspects, the most important is accessibility and universal design (80 %) and generality aspects as lowest (55 %).
### Table 2. Means for value creation

<table>
<thead>
<tr>
<th>Project group</th>
<th>Subgroups</th>
<th>Characteristics or Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG2 – Means which motivate to value creation solutions</td>
<td>Economic incentives</td>
<td>Environmental funds, financial support for testing new trends, branding, rewarding, cost productivity, orientation, investment loan for enhancement / replacement, changing energy consumption, combining different energy resources, emission reduction, support for maintenance and technical upgrading, support for refurbishment, tax reduction, competitiveness</td>
</tr>
<tr>
<td></td>
<td>Knowledge</td>
<td>Good planner, good management, changing regulations, new demands from society, social awareness, user satisfaction, communication ability, creating value with society, organizational development, best practice design, developing know-how training of employees, implementing new cooperation models, developing strategic KPI, knowledge on sustainable efficient building, open for new technical solutions supporting innovative ideas, establishing creative teams</td>
</tr>
<tr>
<td></td>
<td>Contract</td>
<td>Contract process with dialogue, contract division, contract type, contract procedure, selection and award criteria, contracting plan, PPP practice, clear tasks and definitions, contract duration, financial capacity of contractor, allocation of responsibility and risks, clear specification of deliverables, performance targets, measurement methods and standards, active partnership dialogue, organizational measures, developing strategic SLA,</td>
</tr>
<tr>
<td></td>
<td>Processes and assurance quality</td>
<td>Process management ability, communicating value, political support, user’s participation, performance requirements for each phase, mechanisms and procedures for ex-ante evaluations, mechanisms for ex-post evaluations, monitoring, inspecting, evaluating, success / failure factors, key performance indicators</td>
</tr>
</tbody>
</table>

For the early phase it is found that competences have an important role. It is seen that some improvements are needed for: experience, higher responsibility, clarification of project organization, increasing of multidisciplinary understanding, better project manager’s competence, including FM experiences in early phase, better competence of LCC, more focuses on value for client/ owner/ user. All this competence must be a part of early design phase. Needs for processes, methods and tools supporting early phase. Needs for instruments and incentives to strengthen behavior to achieve common goal.

### CONCLUSIONS

The main purpose is to get a usable model to gather analyse data from existing housing areas as a base for developing smart urban growth to meet changing social needs for people. Combination of multiMap and Value contribution mind map and a model should turn out to be effective tools for gathering a lot of information. The way of classify information gives opportunity to aggregate data and with new technology to visualize results to obtain effective way of communicate complex information. According with an international trend to strengthen integrated advice in the early stages as the basis for the project’s value over time and in this context of the concept and
function of “Value Management” to coordinate the various actors’ values before designing the project (Shen, 2013), the project looks at the needs and content that is in the function to ensure the requirements for the owner’s / user’s added value in the use phase.

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COMFORT QUALITY IN THE ARCHITECTURAL TRANSFORMATION OF EXISTING FACILITIES

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ABSTRACT

Our cities lose part of their past daily. The transformation of the existing, in essence, should recognize and retain the quality of the built, along with a new layer of meaning - an expression of contemporary. The aim of this study is in the perception of contemporary technologies in relation with interventions on existing buildings in terms of comfort on the example of new building of the Faculty of Architecture, Civil Engineering and Geodesy in Banja Luka, rendering the transform and build annex of an existing facility within the area of the University City.

In the existing building called ‘Teresa’ constructed during the Austro-Hungarian rule, we tried to recognize the quality that should be protected, with the introduction of a new spatial context transforming the building to contemporary needs. The identity and ‘heart’ of the new school are placed in the central hall, between the existing and the new. Given the complexity of this task, not only when it comes to building a new identity and quality of places to stay, work and education, but also the specificity of the assignment in three study program, the paper presents the quality comfort in school produced through interspace, space where are separated and integrated two parts of building.

Keywords: transformation, reuse, comfort quality, faculty building

INTRODUCTION

The Faculty of Architecture, Civil Engineering and Geodesy in Banja Luka has no building of its own and since 1996 when the Faculty was founded the classes have taken place at several different locations in the city. In 2008, the Faculty and the University of Banja Luka launched the initiative to prepare the preliminary design and later on investment and technical documentation for construction of the new building of the Faculty of Architecture, Civil Engineering and Geodesy in Banja Luka within the compound of the University City of Banja Luka.
The location for construction of the Faculty building has been found in the complex of the former JNA barracks, 'Vrbas', now a part of the compound of the University City of Banja Luka. As an area of landscape architecture which has a public character besides its rich horticultural flora planted in different periods of time in addition to rich vegetation and birds fauna of the Vrbas river which runs on its eastern boundary, the initiative was launched to declare the area protected. University City of Banja Luka has been placed under protection of the Republic of Srpska by the relevant decision of the Ministry for Spatial Planning, Civil Engineering and Ecology in 2012. (University of Banja Luka, 2012)

Natural area in the University City of Banja Luka has become the most important park in Banja Luka and is officially on the list of protected areas due to its natural and historical importance. There are 1,500 trees in the area, particularly sticking out lines of plane trees some of which are several hundred years old, 48 species of birds, some of which are protected by the law.

Figure 1: Central pedestrian alley in the University City of Banja Luka, Photo by author

From the point of view of architecture, this area represents a heterogeneous group of facilities of very different purpose, time of construction, architectural form and material realization. In that sense the main task during the process of construction of the new Faculty building which we, as authors, presented in the Preliminary Design, was establishing of new qualities and way of behaviour in this specific space as well as establishing of order in the morphological structure of the University City in accordance with the spatial context which is dominated by the existing natural setting.

Current dynamics of contemporary society which is characterized by strong changeability and destabilization requires elements that would secure safe reliance. Adaptation and renewed use of found, inherited facilities in the area of the University City enables that reliance, sense of security and feeling of continuity as an important positive input for new future holders of identity of this space. Architectural solution which means intervention onto the existing, previously built facility has to deal with a burden of preconditions which need to be accounted for.

PLACES – TERESA TRANSFORMATION

Transformation of existing facilities as one aspect of building transformation is not, of course, a phenomena invented in this region but a very common and frequent way of creating new useful space. Different needs and requests during various periods of the life span of the building have led to such a type of construction where the renovation of existing facilities includes overbuilding or extension for the purpose of getting larger usable space. This type of interventions to the
existing facilities often leads to alteration of the main idea and original idea of the author whereas integration of the existing with the new part of the building into a single architectural unit presents the biggest challenge for the author.

Cultural - historical monuments and inherited architectural structures have to be seen as a live organism and vital space for its beneficiaries. Constant changes in functional use, social and political context and economic development are manifested through spatial interventions. They should have a contemporary language signature while historical authenticity and integrity of the location should not be jeopardized. Once harmonized, the inherited structure and contemporary interventions particularly contribute to the value of the urban space and entire ambience as the old and the new add to their value. There are more and more examples of dealing with spatial co-existence of the different with ever rising consciousness that facilities are never finalized, that they continue to live, change and adapt to the time. (Čvorov, 2011)

Possibilities of architectural organization and material realization of overbuilt space and its form are in causal relationship and the optimal solution is the result of its adaptation. During transformation of existing facilities, the form of extended structures might to a smaller or larger extent be conditioned by the environment, i.e. by urban planning conditions such as the example of the Design for the new building of the Faculty of Architecture, Civil Engineering and Geodesy in Banja Luka. The Design for the new Faculty building has foreseen the intervention to the existing building "Tereza", which is located in the central part of the University City. The building itself was built in 1889, during the Austro-Hungarian Rule and served for military purposes. The Facility which is out of use for many years, has been in a very bad condition prior to the commencement of construction works. Still, it had been occasionally used for holding classes, student workshops and as exhibition area. Its aesthetics of simplicity, its proportions and regular repeating rhythm of spatial elements carry the tone of another era and its spirit is reflected exactly through the emotions it might produce.

We have tried to keep the quality and to convey the spirit of the existing but with clear marking of the building with the new layer of meaning as the expression of the current time through the transformation of the existing building. The intervention to the 'Tereza' building which included rehabilitation, reconstruction, extension and overbuilding of the existing facility is clearly marked by the dialogue between the old and the new. The aim was to preserve the essential character of the building and to introduce new meaning through transformation in order to accomplish its new functional role and identity.

Figure 2: ‘Tereza’ Building’, 2011, Photo by author
Lab of knowledge on technologies and the environment

Spatial requirements of the building are defined by the current and planned number of students and academic courses which take place at three Faculty departments. Being led by the principle which Herman Hertzberger refers to by saying that the task of the architect is not setting of ready-made and perfect solutions but giving possibility to offer the conditions for its upgrading to the beneficiaries and also taking into consideration modern tendencies in academic teaching, we tended to improve the conditions for students and professors in the new building as inspirational laboratory of knowledge. Being aware that there are no given solutions in architecture, the new building connects seemingly unsolvable tensions in the opposites, searches for the meaning of unclear circumstances in the creative process in our consciousness without the intention to deal with all contradictions at any cost. [3]

The existing building with traditional elements of style is connected to the modernly shaped, newly built part of the building. Combination of the old and the new has been offered here as an answer to the aspiration toward acceptance and identification on the part of its new users-students. The volume of the newly built part of the facility is differentiated from the existing building while the defined heights of storeys are being followed very strictly and transferred to the new part of the facility. Architecture of the new facility has been reduced to the container box whereas only the airy hall, the glass cube, connects the new and the old building and represents the higher quality which makes the building special. The entire concept of the school space is focused to this area in-between the old and the new facility and not to the facilities themselves. The zone between the two entities, between the interior and the exterior is active and dynamic space of the hall which enables different relations: it captures the outside space, offers vision into the indoor space and opens toward the nature.

The spatial quality that we strived to achieve here is inseparability of the building from its context. A modern city implies public spaces which to a large extent remind of indoor space and vice versa, indoor space loses its intimacy due to development of modern technologies. Traditional division on the outside and inside has no longer meaning except that there is an inversion in the view. (Kordić, 2012)

TECHOLOGIES – COMFORT QUALITY

Modern technology, which is based on the use of computer software in the design phase of architectural structures have enabled us to new ways of designing and it’s complex managing. The analysis of input data and insight into the possible future scenario of life of the building today is greatly aided by various software packages. Through the project for the new building of the Faculty, we anticipate its use in accordance with environmental principles of sustainable development. Rational use of natural resources, effectiveness in meeting the needs for comfort (temperature, lighting, air quality and noise levels are acceptable) and minimize the amount of waste we have tried to achieve through the principles of “passive and zero positive building”. The school is designed without active heating system and air conditioning fossil fuels, with controlled ventilation / for the successful teaching process is necessary to provide up to 30 m3 / h of fresh contributing to air per student / . The goal was incorporate an increased standard in the education process. School thereby becomes responsible, as a young man educated in this institution would be additionally inspired by elevated comfort of the building, and during the process of education could be actively introduced to the application of modern technologies. (Stanković, 2015) We believe that the transfer of knowledge and modern technology would promote science on the right path towards the future (on the proclaimed principles of practical sustainability). In this sense building should ensure: stability, durability, thermal, acoustic, light, air, visual, and other types of comfort. Its façade system should act as the skin, protecting it from the impact of climate, but also allows it to breathe. Technological required multiple layers of the surface of the
facade and changes over time are an inspiration and encouragement for innovative solutions facade system.

Many of the flaws in the form of thermal bridges, lack of protection from sound and other types of protection, posing a significant threat for comfort in architectural buildings. Not to be overlooked either man midfield where problematic facade is perceived in everyday communications. Certain technological and physical characteristics have been recognized as created visions of the desired comfort and protection from the climate. The architectural language of the spirit of the times is essential for successful implementation with respect to cultural, social, socio-economic, aesthetic, environmental guidelines, as a framework of engagement.

**The sustainability concept**

The scope and character of energy efficiency is determined by the estimated future energy performance of the building, which determines maximum power consumption for heating (and cooling the facility) by the amount of up to 15 kWh/m2 per year, primary energy consumption to 120 kWh/m2 per year, and the air tightness of the outer layer is n50 ≤ 0,6 h-1. (Stanković, 2013)

The main sources of heat in the building are the heat pumps that operate by water – water system. Analysis of the well water abundance on the facility site, made in early 2012, indicated the individual capacity of a water source with about 3,5 l/s, the minimum temperature of well water in winter of 12°C, while in the summer the maximum temperature is 15°C. The total value obtained in four wells explored fully meet the total demand for energy needed for heating and ventilation of the future building which is 9,0 l/s.

All the rooms that are heated are connected to the central system for insertion of the fresh and removal of contaminated air with the return of heat. In order to optimize energy consumption and rationalize the entire investment, the required energy standards are arranged in the building on certain functional and spatial units. Thus, the spaces in the old and the new part of the building are determined by the passive standard, and the central internal communication between these two parts is defined by low-energy standard.

In the rooms with the air capacity per person than 100 m³/h air quality sensors are planned in terms of the amount of SO2, while in the rooms with the air capacity per person than 100 m³/h, there are sensors for the presence. These devices automatically regulate opening of the external hole which is managed by the integral central system and electronic data processing. These devices can perform automatic opening of external frames, which is managed through the integrated central system of electronic management and data processing.

As a part of the sustainability concept and maximum utilization of energy out of the renewable sources, it is forseen to install transparent photovoltaic panels on the remaining central hall which is located between the two parts of the object. Electricity generated in this way allows the minimum consumption of electricity in public power system of the Republic of Srpska. In order to rationalize the consumption of electricity in the building, project documentation provides the application of energy saving light sources with optimized number and position of lamps, VAV control, all within an integrated central system of electronic management and data processing in the building. Considering these measures the newly designed building belongs to the category of passive buildings A+, i.e. buildings that are able to produce as much energy as it is required for their operating.

The values of estimated consumption of energy used for heating the building is 8,1 kWh/m2 per year and the total energy consumption of 14,8 kWh/m2 per year, classifies the FACEG building in energy efficiency class A+. (Čvor, 2014)
Table 1: An overview of energy consumption per item (Čvor, 2014)

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Energy carrier</th>
<th>Estimated (kWh/m² a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heating</td>
<td>8,1</td>
</tr>
<tr>
<td></td>
<td>Ventilation</td>
<td>2,6</td>
</tr>
<tr>
<td></td>
<td>Hot water</td>
<td>0,9</td>
</tr>
<tr>
<td></td>
<td>Lighting</td>
<td>2,9</td>
</tr>
<tr>
<td></td>
<td>Other items</td>
<td>0,3</td>
</tr>
<tr>
<td></td>
<td>Cooling</td>
<td>-</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>14,8</strong></td>
</tr>
</tbody>
</table>

Table 2: Energy consumption balance (Čvor, 2014)

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Energy carrier</th>
<th>Heating energy</th>
<th>Electrical energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final energy (kWh/m² a)</td>
<td>-</td>
<td>-</td>
<td>14,80</td>
</tr>
<tr>
<td>Primary energy (kWh/m² a)</td>
<td>-</td>
<td>-</td>
<td>36,00</td>
</tr>
<tr>
<td>CO₂ emission (kg/m² a)</td>
<td>-</td>
<td>-</td>
<td>11,00</td>
</tr>
<tr>
<td>Total emission CO₂ (t/y)</td>
<td>-</td>
<td>-</td>
<td>74,60</td>
</tr>
<tr>
<td>Total emission CO₂ (mtCO₂e)</td>
<td>-</td>
<td>-</td>
<td>67,70</td>
</tr>
</tbody>
</table>

CONCLUSIONS

In terms of environmental quality, architectural objects are not just a shelter or barrier against certain adverse impacts, but it should be seen as a selective filter for accepting positive influences, such as natural lighting, solar radiation, natural ventilation or a particular architectural design expression. The importance of architecture in defining the quality of the environment, and thus defining the measures for providing comfort in the space has immeasurable importance. Design and construction of facilities in order to improve living conditions, reduce energy consumption and preserve the environment includes defining the basic elements of the functional organization and architectural materialization and shaping, in line with the objectives of sustainable development. Different buildings design principles and applied ways of materialization affect the expected level of energy optimization for all the elements of comfort for people living and working in a certain area.

For an architect it is important to control the environmental conditions in the building design process, mainly heat, air, light and sound. Rayner Banham in his book "The Architecture of the well-tempered environment" posits that the conditions of comfort in the room can provide the buildings / passive control comfort / or use of energy / active-controlled comfort /, and when we had an unlimited supply of energy, we could provide comfort or the quality of life without the buildings themselves. (Banham, 1984)

In most cases, we relied on joint effects these two types of comfort control. At the present time, when we came to the conclusion that traditional sources of energy / coal, oil, gas, etc. / are final, on the road of the final exhaustion and their accelerated use has serious consequences for the environment / SO2 emissions, global warming and local air pollution/, one of the main goals of architecture becomes providing satisfactory conditions of comfort in the area with little or no use energy, apart from the immediate environment or renewable sources.

Thus, in order to achieve optimally conditioned comfort in space and energy optimization, deposit architecture is:

- to exam given influential factors of comfort / conditions on site, microclimate, daylight, air pollutants, noise and others. /,
to establish the limits of preferred or acceptable conditions of comfort in the space / temperature, lighting, air quality and acceptable noise levels /,

• attempting to control this variable parameters / heat, air, light and sound / with the help of passive assets / characteristics of the building / as far as possible and practicable,

• to reduce energy consumption for control and maintenance of active means of providing comfort / heating, cooling, ventilation, lighting, noise and others. /[1]

During the transformation of the existing, the main task facing the authors was the relationship between the historically layered architecture and its extension whose architectural elements and their realization co-relate to modern way of shaping space. Final result has been planned to include qualities of all elements of architectural expression, the old and the new, making a unique and complete work. Essential condition for us was to notice individuality, uniqueness of space which in this case refers to the University Park which is on the list of protected landscape facilities due to its vegetation importance. The attention is focused on identifying the values of the context so it could be transposed into the well thought concept which enables construction of the place, inspirational for work, future factory of knowledge.

REFERENCES


