How the integration of n- dimensional models (BIM) and GIS technology may offer the potential to adopt green building strategies and to achieve low cost constructions.

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Key words: n-dimensional models, BIM, green building, energy efficient building, IFC, integration of BIM and GIS, CityGML, cost and facility management.

SUMMARY

Concerns about climate change and energy dependence, as well as an economically driven focus on increasing efficiency and building performance in a cost-effective manner, have led many representatives of the construction industry to adopt green building strategies. This trend has been encouraged by legislation so as to accelerate the research on key technologies in the fields of energy efficient construction processes, products and services.

Two dimensional (2D) methods of design, planning, construction and operation of facility are no longer adequate, while a combination of n-dimensional tools leads on these fields due to the modern conditions that include growing environmental concerns and economical crisis. Building Information Model (BIM) represents the development and use of computer generated n-dimensional models. It’s a data-rich, object oriented, intelligent and parametric digital database of a built facility.

Green building is rapidly transforming the design and construction industry. Simultaneously a growing number of industry practitioners embracing the advantages of BIM. As a logical development of these trends, green building project teams are increasingly discovering how BIM tools can help them achieve more sustainable outcomes.

BIM adoption is much slower than anticipated, because of technical and managerial reasons. Some of the technical reasons can be surpassed by the integration of BIM with GIS technology.

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1. LEGAL FRAMEWORK FOR GREEN POLICIES

Numerous initiatives have already been launched in cities so as to raise public awareness of the environmental impact of individual consumption behaviors, as well as to promote the sustainable use of energy, water, raw materials and land by individuals and communities.

The Action Plan for Energy Efficiency estimates that the largest cost–effective energy potential lies in the residential and commercial buildings. As a result the Committee on Housing and Land Management of United Nations (UNECE), the European Commission (EC) and other institutions have acknowledged that Construction Industry is a key sector in terms of energy efficiency goals.

Specifically Committee on Housing and Land Management of United Nations has adopted the Action Plan for Energy-efficient Housing in the UNECE Region and recommended UNECE Member States to adapt the targets and measures to local conditions and to implement policies with a view to removing barriers to energy efficiency and to progressively moving towards a low energy and carbon neutral housing sector. The overall aim of the Action Plan is to establish the necessary institutional conditions to improve housing energy efficiency by developing administrative, legal and financial capacities to implement energy-efficiency measures, promoting private and public investments into energy-efficient housing, improving the energy performance standards in the housing sector and encouraging behavioral change with regard to energy demand practices to housing. In addition the proposed ecological housing principles to guide the UNECE policy framework are the following : a) better standards for environmental energy performance of dwellings, b) transformation of the housing sector towards climate neutrality, c) improvement of energy efficiency in existing housing, d) sustainable housing maintenance and utility systems and e) affordability of eco-housing. Additionally International Council for Research and Innovation in Building and Construction (CIB) has a large number of focused groups in the above matters, such as TG066 Energy and Built Environment and TG069 Green Buildings and the Law.

Furthermore European Commission has recognized ‘Energy Efficient Buildings’ as a key target for improving the use of energy and decreasing GHG emissions. As a part of the European Economic Recovery Plan, the Commission proposes to launch partnerships between public and private sectors to further develop and demonstrate green technologies, energy-efficient systems and materials in buildings with a view to reducing radically their energy consumption and carbon emissions. Also, the proposed recast of the Directive on the Energy Performance of Buildings (EPBD) introduces a general framework for a methology to calculate the energy performance of buildings. Information and Communication Technologies for environmental sustainability (ICT) sector should work together with building and construction sector so as to promote interoperability between auditing tools and building and energy management systems, with a view to developing a systematic understanding of a building's energy performance. More specific ICT will help improve energy efficiency in buildings through for example, better monitoring and controlof energy consumption and advanced lighting systems. The EPBD directive underlines that all Member States should apply a methology, at national and regional level, so as to calculate the energy performance of buildings on the basis of the general framework. The energy performance of a building should be expressed in a transparent manner and may include a CO2 emission indicator. Therefore the overall objective of E2B European Initiative (E2B EI – Energy Efficient Buildings) is to deliver and implement building and district concepts that have the technical, economic and societal potential to cut the energy consumption in existing and new buildings by 50% within 2030, thereby contributing to improve the energy independence of EU. To reach this goal implies a holistic combination of technologies that are needed to realize the building concepts. These technologies include ICT as a key element for improving energy efficiency in buildings. The E2B EI will speed up research on key technologies in the fields of energy efficient construction processes, products and services, in order to address climate change issues and to improve EU energy independence.

At a time when public focus remains on buildings' efficiency and it garners legislative support, the creation of energy efficient buildings requires the economical and sustainable use of resources, design and construction. In order that to be implemented, construction industry must have the technology tools to find the best solutions and software developers should create those tools.

2. BUILDING INFORMATION MODEL (BIM)

Planning in two dimensions is no longer adequate for today's society in the light of the increased complexities to be accommodated along with the extended range of opportunities digital technology afford. Building Information Model (BIM) has recently attained widespread attention in the Architectural, Engineering and Construction Industry (AEC). It represents the development and use of computer generated n-dimensional (n-D) models to simulate the planning, design, construction and operation of a built facility. It helps to visualize what is to be built in simulated environment and to identify potential design construction or operational problems.

It's a data-rich, object oriented, coordinated, intelligent and parametric digital representation of a built facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and to improve the process of delivering facility.

The extended use of 3D intelligent design (models) has led to references to terms such as 4D (adding time to the model) and 5D (adding quantities and cost of materials). In particular BIM is a 5D model that combines construction duration information and sequence (4D) with cost (5D). These 2 dimensions are attached to drawing elements that represent building systems (3D). Perhaps a simpler way is to think 3D model as a 'tool', then the applications of this use throughout the planning, design, construction and facility operation processes are almost infinite. When coordinating constructions sequencing by integrating schedule data with the model data and calling it 4D, or doing the same when using the model data to quantify materials and apply cost information and calling it 5D, seems arbitrary since these are just two of the many applications of how the 3D tool can be used to improve all of these processes. In other words, a computer program can animate construction progression. A user can input a date to observe current state of completion. The builder can analyze on-site material problems, develop phasing plans, improve the sequencing of trade contractors or analyze the cost of construction delays. Cost can also be attached to drawing elements that represent building systems for estimating and value engineering. The estimate can progress in lockstep with design.

BIM carries all the information related to the building, including physical and functional characteristics and project life cycle information, in a series of 'smart objects'. By using BIM-based methods stakeholders take more and better informed decisions earlier in the life cycle of a built facility thereby reducing costs, delivery time and environmental impact as well as improving communication, productivity and quality.

It can be used for the following purposes: visualization, fabrication, code reviews, forensic analysis, facilities management, cost estimating and construction sequencing and collision detection. In addition building performance and predictability of outcomes are greatly improved by adopting BIM. As the use of BIM accelerates, collaboration within project teams should increase, which will lead to improved profitability, reduced costs, better time management and improved customer/client relationships.

The key benefit of BIM is its accurate geometrical representation of the parts of a building in an integrated data environment and that can be used to analyze its performance.

Other related benefits are: a) information is more easily shared and can be value-added or reused, b) better design, c) controlled whole-life costs and environmental data (environmental performance is more predictable and lifecycle costs are better understood), d) documentation output is flexible and exploits automation, e) lifecycle data (requirements, design, construction and operational information can be used in facilities management), f) higher quality of work performance (ability to identify collisions and to visualize what is to be built in a simulated environment), g) better coordination among design and engineering work (fewer errors and corrections in the field, higher reliability of expected field conditions), h) increased speed of delivery and i) allows to the contractors the opportunity to do more prefabrication of materials offsite, which is usually a higher quality at a lower cost.

On the other hand, BIM adoption is much slower than anticipated. There are two main reasons, technical and managerial. The technical reasons can be broadly classified into three categories: 1) the need for well defined transactional construction process models to eliminate data interoperability issues, 2) the requirements that digital design data be computable and 3) the need for well-developed practical strategies for the purposeful exchange and integration of meaningful information among the BIM model components.

The most frequent obstacles to implementation of BIM technology are the following: a) necessity to concurrently perform the activities of design and construction, b) divergent protocols of data input and extraction, c) the lack of an appropriate software platform to catalog all the aspects of the project and d) the lack of sufficient infrastructure to provide access to the model by all members of the project team.

In the past, facilities managers have been included in the building planning process in a very limited way, implemented maintenance strategies based on as – built condition at the time the owner takes possession. BIM modeling may allow them to participate in a much earlier stage, where they can influence the design and construction. Moreover an integrated BIM model is valuable to facility managers, because it may contain warranty data, useful life expectations, maintenance recommendations, remodelling and renovation documentation. Even though there is a lack of interoperable data exchanges throughout the buildings' lifecycle. BIM is being used during design and construction phases but needs to be applied throughout the lifecycle to include facilities management (FM). There is a need to look beyond design for construction phases and begin to use BIM for a design for maintenance strategy.

Nearly all the experts expressed their need for better software integration. The two types of software most frequently mentioned are energy performance modeling software used by engineering firms and facility management software used during building operations and management. In both cases, the software cannot currently utilize the depth of data available in the BIM model. Better software integration will allow project teams to utilize the BIM model more thoroughly and compare real building performance results with initial rough estimates. The ability to see an integrated view of all the building systems would improve sustainable outcomes by capturing the impact of design decisions across multiple parameters, allowing for more well-informed design decisions.

Future challenges for more useful implementation of BIM include: a) model servers for near real time information sharing and cross-disciplinary collaborative work enabling truly integrated design, b) integration of BIM with real time operational information to support facility management and operation as well as various life cycle support services, c) catalogues of re-usable knowledge, such as materials and components, with built-in parametrics and constraints to support configuration of customized design solutions.

The next generation of BIM applications will include better interoperability and more effective analytical tools, including energy lifecycle analysis. It can be a vital green design tool, because it allows users to weigh various design options and their corresponding impact on green building performance. When the building's size, shape and orientation are developed to perform in conjunction with natural elements, requirements for heating, cooling, ventilation and electrical loads can be reduced substantially. Technology software firms are busy working on the next generation applications that focus on interoperability, integration and fostering a collaborative design process that improves constructability within budgets and schedules and engenders better green outcomes. As a result, developers of BIM applications have become one of the driving forces behind interoperability standards such as the Industry Foundation Classes (IFC), which allows the exchange of the 3D model's information for generating building simulations across multiple applications. Other strong needs among design and construction are the effective management of large quantities of data and the translation of information to an analytical tool.

3. GREEN BIM

A reduction in energy consumption provides the largest impact for sustainability and efficiency. The creation of a comprehensive operation and maintenance plan within a BIM program could assist this effort, because the ability to lower energy consumption requires an efficient model to help manage the large volume of collected data.

BIM focuses on information exchange in order to achieve full energy management control within a single computer model. The adoption of COBie (Construction Operations Building information exchange) and the other exchange standards would help eliminate waste associated with creating, reproducing, processing and archiving paper documents.

Green design is best served by an integrated design process, with a holistic approach to all design and construction disciplines, and BIM adoption is in part based on its ability to facilitate integrated design. Also, green design and construction rely on improving building performance. Many of the tools of BIM, including energy use modeling and day lighting studies provide better information on how design changes impact building performance than any traditional design tool. BIM models can also provide more information to product manufacturers, allowing for greater use of prefabrication, which can eliminate waste and makes the construction process greener and faster.

Because of the way BIM facilitates green design, construction and sustainable outcomes, the growth of green building as an accepted, widespread practice is helping to accelerate BIM adoption. BIM tools enable highly sustainable outcomes through energy performance simulation, prefabrications, green renovation and retrofit projects in existing buildings and also verifications.

The most common activities undertaking by Green BIM practitioners are energy performance, lighting analysis and HVAC design. All these have a major impact on building performance in terms of carbon emissions, energy use and cost savings. HVAC design also impacts indoor air quality, which is another key green building consideration.

BIM models are used in calculating LEED credits. BIM tools are used for energy simulations, lighting analysis, water conservation modeling that may increase with both a higher level of sophistication of LEED rating requirements and improved functionality of technology. Providing BIM models to building product manufacturers to prefabricate building elements off-site offers many green benefits, including the reduction of waste produced by onsite fabrication. Prefabricated elements can include complicated HVAC or electrical systems in buildings.

By using BIM, contractors realize efficiencies that can reduce consumption to reduce material waste and resource consumption to improve the overall carbon footprint of a project. Matching design strategies with verified results will allow firms to refine their green building strategies, and owners can track quantifiable returns on their investment, which could in turn lead to higher levels of green building investment.

4. INTEGRATION OF BIM AND GIS TECHNOLOGY

BIM has enormous potential to increase efficiencies, especially when connected with geospatial information systems (GIS). The integration of BIM and GIS has some targeted application areas, such as: urban and landscape planning, architectural design, 3D cadastres, environmental simulations, etc. In addition that integration of GIS and BIM world comes from a need to use building-specific information in a bigger spatial context for queries and GIS analysis. Geospatial information can be used in future urban planning when it comes to designing new buildings. Ideally this exchange will happen via web services, which have the biggest range of users when using open standards. For example, cloud computing is having a huge impact in relating buildings in their physical locations. Now we can overlay BIM and GIS data. We can place a building in different geographical settings and see how it impacts structural requirements. One major benefit of cloud computing is the sheer volume of information available through internet. People in different cities can work on the same design project together in real time without consuming vast resources on their individual computers. With overlays of Google Earth and other tools, the opportunities are endless.

Open Geospatial Consortium (OGC) created a workgroup aimed at achieving the integration of CAD/BIM and GIS technologies on the web. The OGC offers a platform to develop and test the new standards that can be used to exchange spatial data. Its interoperability program aims to promote and guarantee interoperability for the spatial data user market. CAD/BIM and GIS technologies can be integrated by using open standards. It is now possible to exchange data from architecture, engineering and the construction industry (AEC) on the web and use it in a GIS environment where GIS operations can be carried out with the data. Object oriented building information in 3D is currently available in Google Maps via tools such as SketchUp. The OGC acknowledges that there is great potential for offering and exchanging building-specific data on the web. Making AEC data available in GIS environments has been tested, and the time has come to develop an OGC standard in this field.

A neutral data format has been developed to describe building-specific data, namely IFC (Industry Foundation Classes) for interoperability and sharing of building information models (BIM). This was done by the IAI (International Alliance for Interoperability - BuildingSmart), which is connected to the OGC. IFC modeled data are mostly file based and exchanged as files (as snapshots of a BIM) by project partners. IFC and BIM usually model buildings and structures above the ground. It is typically used for new buildings and structures. In parallel, two complementary standards are being developed: Information Delivery Manual (IDM) and Model View Definition (MVD) that specify which information is to be exchanged in each scenario. International Framework for Dictionaries (IFD) is a standard for terminology libraries or ontologies. It allows information to be found and understood by humans using natural language. It also supports globally unique identification of objects. The vision is open interoperability and full life cycle implementation of BIM-based methods and tools. Information is shareable between various ICT tools of different stakeholders without re-entry and loss of semantics.

IFC which represents a semantic structure is a data format that covers every phase of a building’s life cycle. IFC is supported for BIM by most large tools. However, it’s not accessible via web services, as no standard was available for it at the time OWS-4 was formed. OWS-4 created an extension for the already existing Web Feature Service for GML with some data options. The chosen data format exchange IFC is GML. With this is now possible to save multiple georeferenced BIMs on a server, categorize, show and edit sub-BIM features with queries. Retrieval of BIM features can happen with both IFC and CityGML. The latter provides rich semantic framework for representing urban features and their relationships with each other, but it has not been developed to serve as a medium for building activities and therefore is not to be used as such for AEC data. When it happens via IFC, a translation to CityGML is necessary. Although entire BIM models can be shown, sub-BIM transactions cannot be supported yet because of complexity of minimal mutations inside a building, which has something to do with the richness of IFC. In combination with CityGML, IFC can be used to display 3D buildings in a bigger spatial context and exchange them via web services. When being loaded into a GIS environment, BIM data is suitable for spatial analysis.

An effort for conversion of IFC to CityGML has been implemented in the open source Building Information Modelserver with the development of a CityGML extension called ‘GeoBIM’ so as to get semantic information IFC data into a GIS context. It is not possible to integrate IFC semantics into CityGML by default. A new CityGML extension will create the possibility to integrate IFC semantics and properties. The open source BIMserver will be able to export IFC data to CityGML, including the IFC geometry but more important also the semantics and properties. This extension on CityGML for IFC data is called ‘GeoBIM’ extension. The development and growing use of both CityGML and BIM servers may create a breakthrough in the integration of the two worlds.

5. CONCLUSION

At a time when creation of energy efficient buildings requires the economical and sustainable use of resources, design and construction and incentives in that field continues to garner legislative support, construction industry must have the ICT tools to find the best solutions, in a cost-effective manner. Combination of n-dimensional tools, such as BIM, leads on design, planning, construction and operation of a built facility, because of the current trends, that includes green design, construction and sustainable outcomes. The growth of these trends is helping to accelerate BIM adoption. BIM's adoption by construction industry will be increased, since some technical obstacles will be surpassed. That will happen in some point, with the integration of BIM with GIS technology.

REFERENCES

Words and Images (July 2009) "Building Information Modeling: Understanding and Operating a new Paradigm", The Foundation of Wall and Ceiling Industry

"The Contractors Guide to BIM, edition 1", AGC – The Associated General Contractors of America

Eddy Krygiel, Brad Nies foreword by Steve McDowell, FAIA, BNIM (April 2008) "Green BIM: Successful Sustainable Design with Building Information Modeling"

Salman Azhar, Micheal Hein and Blake Sketo (August 2008), "Building Information Modeling (BIM): Benefits, Risks and Challenges", McWhorter School of Building Science, Auburn University, Alabama

Journal of Building Information Modeling (Spring 2011) "No BIM for you" JBIM an official publication of the National BIM Standard (NBIMS) and the National Institute of Building Science (NIBS)

McGraw_Hill Construction – SmartMarket Report (Fall 2010) "Green BIM, How Building Information Modeling is contributing to Green Design and Construction"

Marcus White (July 2007) "The plan is an adequate tool for planning: Enhancing the urban design process through the use of 3D+ digital tools directed towards sustainability", RMIT University, Melbourne Australia

Leon van Berlo, Ruben de Laat (November 2010) "Integration of BIM and GIS: The development the CityGML GeoBIM extension", Netherlands organization for applied scientific research (TNO)

Eric Van Rees, (January 2008) "BIM Data Exchangeability with New WFS for GML", GEO informatics on line Journal

COM (2009) 111 final. Communication from the European Commission on mobilising Information and Communication Technologies to facilitate the transition to an energy-efficient, low-carbon economy.

E2B EI - European Initiative on Energy Efficient Buildings - Scope and Vision V01 (January 2009)

Report of the Committee on Housing and Land Management on its seventy-first session (September 2010) – ECE

BIOGRAPHICAL NOTES

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