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Virtual Building Environments (VBE) - Applying Information Modeling to Buildings

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ABSTRACT: A Virtual Building Environment (VBE) is a “place” where building industry project staffs can get help in creating Building Information Models (BIM) and in the use of virtual buildings. It consists of a group of industry software that is operated by industry experts who are also experts in the use of that software. The purpose of a VBE is to facilitate expert use of appropriate software applications in conjunction with each other to efficiently support multidisciplinary work. This paper defines BIM and virtual buildings, and describes VBE objectives, set-up and characteristics of operation. It informs about the VBE Initiative and the benefits from a couple of early VBE projects.

INTRODUCTION

Most manufacturers thoroughly test their products before delivering them to the market. In some industries the testing is done on physical prototypes, in other it is done virtually; in many industries it is done both ways. Manufacturers know exactly how their products are going to perform or hold up *before* these products are built and sold. For example, car manufacturers extensively test prototypes (both virtually and on the track) and know how the new models will perform before they start manufacturing them, even if they do not disclose all information in public. NASA thoroughly tested all new space vehicles in the Gemini, Apollo and Space Shuttle Programs in simulation and launched them only after all problems were proven in simulation to have been solved; when unforeseen problems developed later (such as during the Apollo 13 mission), NASA was able to analyze and resolve problems in simulation.

In most developed countries the buildings construction industry, sometimes called the Architecture-Engineering-Construction-Operations (AECO) or Architecture-Engineering-Construction-Facilities Management (AEC/FM) industry, is the second largest industry. Yet, virtually no testing of the primary product of the industry – *the building* – is done before irrevocable and often very costly decisions are made. True, pre-manufactured components *are* often tested at least in some ways before delivery; mock-ups of critical parts of a building *are* built and tested at times; various types of the building’s performance *are* occasionally simulated; and extensive visual simulations (including “walk-throughs” and

“fly-bys”) are becoming the norm. But no testing of the *whole* building in *all* of its *aspects of performance* is performed before the building is delivered. Commissioning constitutes only a partial substitute for testing and is of little help if the building in question needs substantial redesign and/or reconstruction to perform as originally expected.

The product conception-construction-delivery process in most other industries follows the “design-test/verify-manufacture-deliver-warranty” script. In contrast, the AECO industry seems to employ the “convince-build-pray” modus operandi. The designers *convince* the client by demonstrating a *few selected* performance aspects (usually cost and image) he/she can understand – but the designers cannot guarantee – that the building will work to the client’s expectations; the builders *build* the building, and then everyone awaits to *see how the building will work* once it is occupied and in use. They hope for the best, but fear the worst. At best, everybody is eventually *relieved* (even if some feelings have been hurt in the process); at worst, almost everybody involved faces legal consequences.

Given that the “standard of practice” for how buildings are procured and delivered has not substantially changed in more than a hundred years, no other modus operandi can really be expected. Most (building design) decisions are made without testing their effect first. Whatever testing takes place in the design and construction phases is limited to only a few aspects of performance (i.e. it is intended to aid only specific types of decisions); it is infrequent and usually lacks follow up. It is slow and often delays the building procurement and delivery process it is

expected to expedite. It is often very costly and is seldom required, or even accounted for, in contracts.

Obviously, tests and comprehensive verification of performance are very difficult to attain when each product is essentially a very costly “one of a kind,” and when it takes a long and laborious multi-disciplinary effort to design and build it. It does not help that the product is also very complex and complicated, and that smaller scale partial replicas can reproduce only a few of the performance aspects of the product, and even those mostly only as approximations. In similar situations, decision makers in other industries use software that can simulate the product’s performance that is of interest – they build *virtual* products they can experiment with and test with computers. It is clear that the AECO industry will be able to test its product (i.e. buildings) in a comprehensive manner only *virtually* – it will have to first build *virtual buildings*, test them (and make the necessary design and planning modifications) and physically construct them only after that.

The industry has been using industry specific software more than just occasionally for about 20 years, ever since the first versions of AutoCAD appeared on the market and in schools of architecture and engineering. Today, industry use of software extends well beyond CAD with “downstream” applications that model performance relevant to or resulting from different parts of a building’s life cycle. However, unless they belong to an integrated suite of software tools, these applications have little to do with each other – they are “unaware” of each other, often describe essentially same data in different ways, and do not exchange or share data. This is resulting in an unnecessary generation of duplicate data, and is causing a lot of unnecessary errors and omission, cost and delays (Bazjanac 2001).

The creation of virtual buildings and their productive use in experimentation and testing will require additional software and, more importantly, organized coordination among all software that may be used. Some leaders of the AECO industry have realized this and have formed a slew of new organizations and consortia in the last decade designed to bring “new technology” and “software interoperability” to the industry. These include the International Alliance for Interoperability (IAI 1995), the Building Lifecycle Interoperable Software consortium (BLIS 2000), the Continental Automated Buildings Association (CABA 2002), FIATECH to “bring technology to capital projects” (2002), the Construction Users Round Table (CURT 2003), the Open Standards Consortium for Real Estate (OSCRE 2003), to name just a few in North America.

Perhaps one of the most important of these to date is the IAI, because it developed the Industry Foundation Classes (IFC), the first *open* object oriented *comprehensive* data model of building that provides rules and protocols for definitions that span

the entire life cycle of a building. IFC are also the only such model that is an international standard (ISO/PAS 16739). All major CAD vendors have developed their internal “intelligent” data models of buildings; these are designed to support the work of and data exchange within a particular vendor’s suite of tools and are thus limited in scope, are dissimilar and proprietary. Nonetheless, together with non-proprietary developments, these are all beginning to move the users of industry specific software from defining buildings as sets of lines and text that must be interpreted by the observer to defining buildings as *information models*. Definition of buildings as information models will be the foundation in creating virtual buildings with software that can seamlessly access data from the information model, manipulate/use them, generate new data, and return them to the information model.

DEFINITIONS: BUILDING INFORMATION MODELS AND VIRTUAL BUILDINGS

2.1 *Building information models*

Building information modeling (BIM), used as a verb, is the act of creating a Building Information Model (BIM – a noun). While it was apparently a term originally used by Autodesk staff internally, Jerry Laiserin was the first to widely publicize it in the industry (Laiserin 2002).

Used as a noun, a BIM is an *instance of a populated data model of buildings* that contains multi-disciplinary data specific to a particular building which they describe unambiguously. It is a *static* representation of that building (i.e. it uniquely defines that building in a section of time) – it contains “raw” data that that define the building from the point of view of more than one discipline. Data contained in a BIM are also “rich:” they define all the information pertinent to the particular building component. A three-dimensional “surface” model of building geometry alone that is used only in visualization is usually *not* a BIM. A BIM includes all relationships and inheritances for each of the building components it describes; in that sense it is “intelligent.” A data set that defines only a *single* “view” of a building (i.e. that describes a specific single type of performance), such as a data set that, for example, includes all data a structural engineer may need for structural calculations (but nothing more) is, by itself, *not* a BIM.

2.2 *Virtual buildings*

A virtual building is a BIM *deployed in software*. It *simulates* the behavior or performance of a building or building component(s) entirely within a computer system, without any physical construction of the

building or any of its components. A virtual building constitutes the *use* of data that are contained in a BIM to *reproduce* the behavior or performance of a building or building component(s) with accuracy appropriate to the reason for reproduction. The BIM is deployable by a *suite of software* that can reproduce behavior or performance in a *comprehensive* way and, as appropriate, over time. A virtual building is a dynamic building representation, even if a particular single "view" of the building is static.

Any software that can access and use data contained in a BIM to simulate some form of behavior or performance of the building can be part of a virtual building software suite. Different software within the same suite can depict behavior or performance at different levels of detail, as long as each is appropriate for the "view" it represents.

The software is operated by qualified professionals who are experts in both the use of a particular software application that is part of that suite and in the industry discipline that application belongs to. Virtual building operators need this dual expertise to properly resolve or interpret issues that arise from limitations of software, lack of reliable data and/or professional conventions.

3 DATA DEPOSITORY AND ACCESS ISSUES

It takes an enormous amount of data to define *everything* even in small and "simple" buildings. The amount of data to describe a building increases manifold with increase in building size and complexity. The temptation to reduce the amount of data by discarding data in which one has no interest is countered by the realization that *each datum* is potentially of interest to someone else.

As explained above, a BIM contains data that define building status in section of time. To reduce the physical size of a BIM, instead of replicating data available externally (such as manufacturers' product data for some of the building components), it only includes *pointers* to external data bases where such data are available. In the case when a building definition depends on results generated by a software application, instead of capturing the entire (usually large) submission from that software, the BIM contains only data that enable the regeneration of the submission (i.e. the BIM captures only the data needed to reproduce the *input* for that software).

Virtual buildings generate enormous amounts of data on their own. These are measured and/or simulated time based data that are critical to the definition of building behavior and performance. When used in a virtual building, a BIM also includes pointers to data bases that keep such data externally.

The sheer amount of data that define a building can pose problems in data exchange. Standard file exchange is impractical when the file includes a

complete BIM. Model servers which facilitate partial model exchange (i.e. exchange of only some of the data) can solve that problem: The (very large) BIM file is resident in a model server, and "clients" query for and extract only data needed by a particular application. The extracted data, given proper authorization, can come from any part of the BIM: a specific individual datum or data sets that represent a particular "view" (or a set of "views") of the building. Depending on the location of the model server, the data can be accessed directly or via web services.

File exchange usually requires implementation of the same version of the building data model by *both* the generating and receiving software. Data model versioning is typically irrelevant to model servers.

4 VIRTUAL BUILDING ENVIRONMENTS

Despite recent efforts by the leading CAD vendors and the new industry organizations to promote building information modeling as the way to define buildings, an overwhelming majority of building procurement projects is still done the same "old way" by defining and representing buildings in "dumb" 2-D and text documents and with little, if any, use of contemporary IT technology. This is true even though technology *exists now* that can make professional work in most of the industry disciplines *much* more efficient and effective than it is today. The industry in general is resisting efforts to change toward information modeling and creation and use of virtual buildings. The causes for this resistance are found in several pragmatic reasons: steep learning curves, lack of time and adequate funding, and shortcomings of software.

Most software applications that are specific to the AECO industry share a common characteristic: Their proper use requires intricate knowledge of the application and expertise in the corresponding industry discipline. Obtaining such level of knowledge and expertise for all industry software that is used for a given project is very difficult and often prohibitively expensive. End users that have the task to create a "real life" project BIM and use interoperable and non-interoperable software with it can face very steep learning curves and software that is sometimes at best in beta status and cannot easily do what the user expects it to do. They are under pressure to meet tight "regular" deadlines, and seldom have any meaningful additional resources to do their work on a given project in a way different than before. After *briefly* trying information modeling, their typical response is: "This does not work (for me/for this project/for my office/at all)." They then revert to the "old ways" of working and using "dumb" software.

Often overlooked is the impact of the "old way" of procuring buildings on multidisciplinary teams that are assembled to work on a given project. As

currently practiced, their work is unnecessarily difficult: Communication is far from efficient, data exchange is costly and riddled with errors and omissions, data sharing is not practiced and is often practically impossible, and their work is “behind schedule” almost by definition. In addition, their group experience and knowledge is seldom reused in another project and is usually lost after the project is over. The work of multidisciplinary teams could become much more efficient and effective with the use of BIM and virtual buildings.

BIM development and the use of virtual buildings today usually require help. This help is now beginning to be available in the form of Virtual Building Environments that are designed to assist end users of industry software and serve as a “break through” mechanism to get building information modeling and virtual buildings deployed in the industry.

4.1 What is a Virtual Building Environment?

A Virtual Building Environment (VBE) is a place where a group of industry software is operated by industry experts who are also experts in the use of that software. The primary purpose of a VBE is to facilitate expert use of appropriate software applications in conjunction with each other. A VBE employs software applications that, as a group, define a building, its parts, its behavior and its performance. It involves simultaneous or near-simultaneous simulation and display of data generated by multiple sources. A VBE facilitates the manipulation of data that are used in the planning, design, construction and operation of a building. It makes it possible to conduct experiments on the building or its parts, without first erecting them. In summary, a VBE is a *physical place* (i.e. a location) that *facilitates expert creation of and use of virtual buildings*.

Ideally, a VBE follows a building’s entire life cycle, and the selection of software changes correspondingly from that related to design, to that related to construction, to that related to commissioning, to that related to operation and maintenance, and eventually to that related to demolition. The selection of software and participating experts supports broad definitions of design, construction and operations. For example, the construction and maintenance processes can be planned and modeled along with the building itself to evaluate constructability and maintainability early in a project.

Similar to a selected group of software, a VBE involves a group of experts. Group members have the experience, expert knowledge and skills in both software applications and industry disciplines the software is related to. They understand the relevance, the meaning and the quality of data used in a particular industry project, as well as the implications of decisions made in the use of software. They can solve problems and define tasks appropriate to

specific applications, and can create “work-arounds” within a particular application if the application cannot deal with the problem or data as defined.

When a VBE is employed in a specific industry project, the group of experts contains those that have expertise, knowledge and skills relevant to the particular project. From the VBE perspective this *group of experts is temporarily extended* (for the duration of the project) by staff or others from organization(s) that are working on the particular project or are involved with it. From the project perspective these *experts join the project team temporarily* to assist the team so it can more effectively use software needed for the project, create the BIM and test its designs, solutions and/or plans in a virtual building.

4.2 VBE objectives

Other industries, such as automotive and aero-space, have reaped significant benefits from the use of IT. Virtual building environments should help experience and demonstrate *explicit benefits* from the use of contemporary IT in the building procurement process: the use of groups of software to solve multidisciplinary problems, the use of comprehensive project data depositories that contain all project data (including historical), the automation and semi-automation of repetitive tasks, prompt access to expert knowledge, instantaneous distribution of complete data sets to all who need them, seamless and instantaneous multi directional exchange or sharing of interdisciplinary project information, virtual collaboration, concurrent engineering, and much more.

They can provide support to many different types of industry projects that can benefit from the use of virtual buildings. These, among many other, include architectural, engineering and interior design projects to test design alternatives, refine decision, control building cost, and explain and communicate results; new construction and reconstruction projects to foresee and prevent problems in construction and its sequencing, detect insufficient or missing information, and test and explain cost effective substitutions and/or deviations from design documents and specifications; energy conservation projects to test alternatives in heating, cooling and illuminating a building, as well as alternative building energy management strategies; in building security and safety training to explore “what-if” scenarios, prepare first responder teams to provide most effective response in different emergency and disaster situations, and to test different response plans; in capital facilities projects to minimize risk to owners and operators by providing much more complete and reliable information about a given building’s design and construction and its operation throughout its life cycle.

A VBE can be described as a “resource center” or a “center of excellence” that can serve as:

- (a) an industry specific software deployment center for industry projects
- (b) a center of education, and
- (c) a knowledge and technology development center

4.2.1 *Software deployment center for projects*

As a software deployment center a VBE provides immediate expert help in the use of established and new industry software. VBE experts can help industry project staffs select the right software for the project, “hold (their) hands” (i.e., demonstrate how to use the software to accomplish specific tasks) as they start using the software, and advise them in the selection of proper choices they may make in the use of software.

Some of the industry software on the market today is still in initial stages of maturity. Such software cannot successfully perform all of the tasks end users expect it to perform, or it cannot perform its tasks if a building is unusual (i.e. not trivial), complex, complicated or large. VBE experts can find ways around some of these problems (i.e. develop “work-arounds”) and report specific software shortcomings and its causes directly to software developers, so software can be improved. In that way a VBE can become an important factor in making industry software more mature and robust.

Some of the interfaces of otherwise robust industry software to a data model (such as IFC) or other software may not work properly under all circumstances. VBE experts can detect and identify causes of such software interface problems and work with interface authors to correct them.

Many organizations are hesitant to acquire costly new software their staffs do not know how to use, even if it is recommended to them for a specific project. A VBE provides an opportunity to use such software for the project without purchasing it, experience firsthand the benefits from using it, and learn how to use it *before* purchasing it. Thus a VBE can help spread and expedite the use of productive software in the industry.

4.2.2 *Center of education*

A VBE provides opportunities to accumulate relevant knowledge and provides *opportunities to share knowledge and learn*. Few industry professionals have currently the knowledge and experience needed to operate groups of software at the level that is required when dealing with complex and complicated issues and problems. All too often project personnel are unable, hesitant or not in position to start learning on their own. A VBE provides opportunities to members of commercial design and engineering office staffs, construction managers, building operators and officials, code checking and enforcement officials, and others to create a BIM and operate a virtual building under expert supervision, *as they are*

productively working on their project. This provides them with the initial experience of *successfully* doing that, which in turn may lead to the formation of an in-house partial VBE in their organizations.

Industry-wide use of BIM-generating and virtual buildings software requires the support of professional consultants that are at ease with this technology. A VBE provides a framework to teach a *new generation* of such consultants by including them in the work on VBE projects (i.e. industry projects temporarily conducted at a VBE). It provides opportunities to consultants to join project teams and learn new skills (by participating, without compensation, in the work on such projects) which they will then be able to *competently* offer to the industry.

Professional industry workforce will have to develop additional skills that will enable it to effectively utilize the new technology in daily work. With *very few* exceptions, these skills are not taught systematically in today’s professional schools, and many of their graduates do not know or understand this technology and are ill at ease with it. The lack of faculty members at institutions of higher learning who are knowledgeable in this area of industry technology is one of the main reasons for that. A VBE provides opportunities to faculty on leave of absence to work directly on such projects, learn and assemble information needed for the development of new courses and curricula.

4.2.3 *Knowledge and technology development center*

A VBE also serves as a center of knowledge that is needed to identify and solve problems that arise from the use of the new technology. These include problems encountered in information modeling of complex buildings, in massive or selective data exchange, in finding “work arounds,” and in support of newly emerging industry tasks, to name a few. A VBE provides a framework for research and development that will help software developers deliver more useful software.

If not properly staged and controlled, intense exchange of project data can be actually counter productive. Issues of staging and control of industry data exchange are not yet well understood. A VBE provides opportunities to determine the *proper sequencing* between project information developed in different industry disciplines and that needed by software applications not in those disciplines. Without proper sequencing of data exchange, the use of some software may yield meaningless results.

The *limits* of data exchange, data sharing and interoperability among industry software are not clear at present. A VBE provides opportunities to explore and learn what these limits might be, and to explore and define ways of circumventing such limitations.

As a technology development center a VBE provides talent to engage in limited software develop-

ment when such development is needed and is not provided by the industry. When a group of critical industry software (i.e. “mission critical” software that is the primary software used in professional work of an industry discipline) would be well served by *new middle-ware*, the talent at a VBE may develop and disseminate such middle-ware. If a “mission critical” application lacks the *interface* to make it interoperable and its vendor cannot afford to develop it, a VBE may provide a framework to develop the interface. When manufacturers cannot agree on a *common format for their products*, a VBE may provide a framework to develop common product data bases for access by industry software.

As need arises to make additional “mission critical” software interoperable, existing data models of buildings (such as IFC) will have to be extended to expand their functionality. A VBE may provide the necessary framework and expertise to develop and implement *new data model extension schemata*.

5 VBE INITIATIVE

To promote the idea and stimulate the formation of virtual building environments, the Center for Integrated Facilities Engineering (CIFE) at Stanford University, Lawrence Berkeley National Laboratory (LBNL) and VTT (Technical Research Center of Finland) kicked off the VBE Initiative at the end of June 2002. The Initiative is an attempt to plan and create initial virtual building environments that will eventually spread worldwide expert interdisciplinary deployment of multiple industry specific software.

Since most governments, with noted exceptions of those in Finland and Singapore, have shown little real interest and support to change how the AECO industry operates, the change will have to come from within the industry. The AECO industry will have to experience and learn the benefits from developing and using BIM and virtual buildings step by step, one project and project delivery staff at the time. It will have to learn how to improve the way it operates today. The VBE Initiative is a pragmatic *strategy* to start that process.

The main goal of the Initiative is to propagate and operate virtual building environments, create a global *network* of Virtual building environments, and to promote opportunities these offer to AECO firms and organizations – opportunities to bring their “real life” projects to a VBE, to have VBE experts help their staffs do their project tasks more effectively, and to learn new things in the process, all at minimal (affordable) cost. Those who take advantage of these opportunities will have a chance to experience how to reduce professional and overall project delivery costs while increasing the value of their work and product, deliver the building sooner, or

operate the building at a much lower cost with measurably fewer problems.

To be able to properly support experts that are needed for the operation of a VBE, institutions that host a VBE need modest longer term funding not related to or coming from industry projects. Thus, another goal of the VBE Initiative is to stimulate *seed funding* for virtual building environments.

The Initiative has several additional goals that may affect and change how the industry will operate in the future. These range from showing how to change and/or enhance current industry processes to enabling industry software interoperability, and from providing help to “real life” industry projects to educating professionals. Some goals, such as assisting “real life” industry projects, are short term; others, such as helping educate new generations of professionals, are longer term.

Because experts and talent needed to operate a VBE are still scarce, *initial* virtual building environments are by necessity hosted at academic institutions and research laboratories. If the VBE network is successful, the skill and expertise will gradually shift to the industry; the support virtual building environments can provide now will become less unique and the need for it will gradually diminish. With time, as the AECO industry in general becomes more skillful and trusting in the use of the new software and technology and effectively changes its work processes, the need to “hold hands” and assist project staffs, and to serve as centers of education may completely dissipate.

6 VBE PROJECTS

The success of the Initiative so far has varied from country to country. The government in Finland established a VBE at the Tampere University of Technology, and the major Finnish property owner, Senaatti, has started several VBE pilot projects there. The Commonwealth Scientific & Industrial Research Organization (CSIRO) has started a number of pilot projects in Australia.

Seed funding for virtual building environments has been developing very slowly in USA. The work of experts at quasi-VBE facilities is instead mostly funded from requests for *specific expert service* not otherwise available to the industry. In these cases the multidisciplinary work is typically limited to only a small number of disciplines and software (i.e. a small number of “views” of BIM), such as architecture, visualization, mechanical engineering and building energy performance simulation and assessment, or quantity take-off, construction process scheduling and visualization. Opportunities to provide effective VBE support will greatly increase in USA once a vendor supplies *interoperable* cost es-

timating software the results from which the industry can trust.

Still mostly in initial phases of development, existing virtual building environments seem to share a global characteristic: limited number of *resident* experts. By necessity, all virtual building environments in existence so far started “small,” offering VBE experts only in a few of industry disciplines. When needed, other VBE experts are hired as external consultants (if available); this increases the cost to the project and sometimes delays its progress.

In June 2004, two years after the kick-off of the Initiative, its original authors organized a VBE workshop at Stanford University. The workshop showed that several pilot VBE projects are now in progress in different parts of the world. On two projects that started earlier than others the first phase of work has been completed (both dealt with the schematic phase of architectural design).

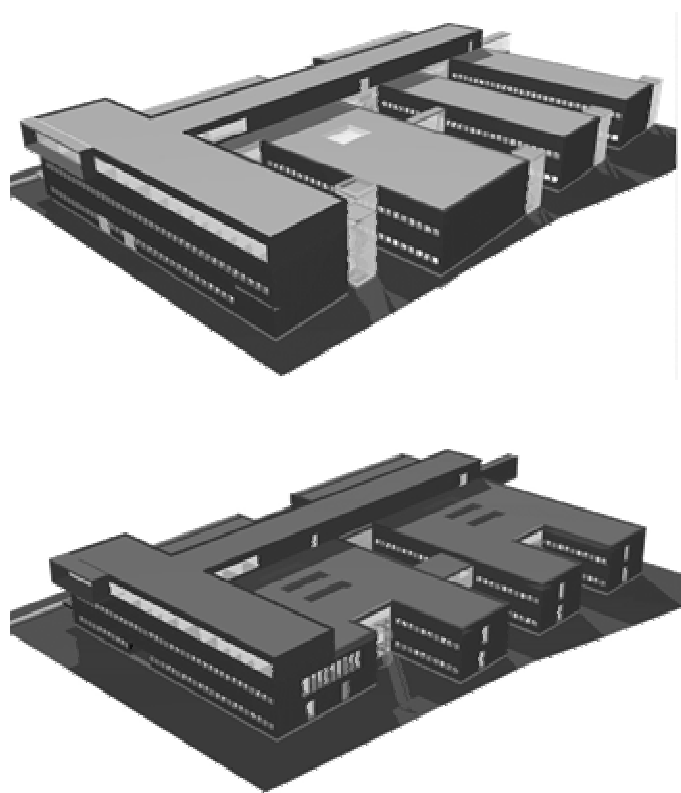


Figure 1. Aurora II design alternatives A (top) and B, compared for construction and life cycle costs. (By courtesy of Jiri Hietanen of the Tampere University of Technology.)

Aurora II VBE project at the Tampere University of Technology compared two design alternatives (Fig. 1) at the project development stage when conventional methods of analysis, based on schedules of spaces and some qualitative information from the building program, yield construction cost estimates expected to be within +/-20% and life cycle cost estimates within +/-25% of later actual costs. By creating virtual buildings for the two alternatives and discussing them simultaneously with the project client in an i-Room (a three-screen interactive work-

space originally developed at Stanford University), VBE experts decreased the inaccuracy of the early construction cost estimate to within +/-3% and the life cycle cost estimate to within +/-5% (Laitinen & Hietanen 2004).



Figure 2. Glare test for a typical office in the e-Lab building using photo-metrically accurate lighting simulation.

The VBE project for the e-Lab at the LBNL (Bazjanac 2002) used virtual building experiments to demonstrate various types of energy performance of typical office and laboratory spaces, as well as the building envelope. Using a suite of 10 different directly and indirectly interoperable simulation and visualization tools it showed *in advance* to the future occupants of these spaces and the client (US Department of Energy) how these spaces will function (Fig. 2).

7 NEW JOB DESCRIPTIONS

When CAD software started being embraced in the AECO industry some 20 years ago, it changed the nature of professional staffs in architecture and engineering. Offices replaced large numbers of “pencil and paper” draftspersons with fewer (albeit somewhat higher paid) CAD operators, who produced more drawings faster. This increased the volume of work and output per payroll unit and soon made offices who switched to CAD more competitive in the market. Information modeling and virtual buildings will inevitably change the office landscape once again.

The most important new job position will be the *Virtual Building Coordinator*. This position will require substantial knowledge in modeling and software use relevant to the different industry disciplines that are part of that office’s business. Qualified candidates will be often hard to find and pricey; this role may have to be filled by special consultants.

The CAD draftsman will be replaced by a *BIM modeler*. This position will require skills in the use of computers and BIM authoring software.

The current VBE experts will evolve into “*high power*” consultants: cost estimators, energy performance analysts, construction managers, etc. They will have the ability to determine the right course of action to resolve a specific project issue, modify and/or interpret information in external data bases, create “work-arounds” for software in their specialties, effectively communicate and explain information, and more.

Another new job position will be that of a *BIM keeper*. Holder of this job will be responsible for the maintenance, safeguarding and administration of a BIM through the life time of the BIM. This position will require at least modest skills in information modeling and substantial knowledge of collaborative engineering.

8 PRESSING VBE ISSUES

Some of the technical issues that surfaced in initial BIM authoring and the use BIM accessing software, such as data incompatibility, data model and software limitations, and problems in file based exchange, were reported earlier (Bazjanac 2002).

It is now becoming increasingly clear that there are other major obstacles that are slowing down the process of moving toward industry wide use of information modeling and virtual buildings. These include *poor quality* of some of the BIM authoring and accessing software (that is buggy, immature and/or not robust), difficulties in reaching *industry wide agreements* in the definition of BIM “views” and/or in implementation of standard data model definitions in software, the small number of *interoperable* industry specific software, issues in *data sequencing* when populating a BIM, problems in managing *different resolution of the same data* as needed by different software, and more.

The complete *lack of aids for end users* is glaring: there are no manuals, templates, case studies published in sufficient detail, nor anything else to guide a newcomer in the initial use of this technology. Missing also is a better understanding of measurable benefits from the use of information modeling and virtual buildings, and of ways to measure them. Recent work at CIFE (Fischer & Ju 2004) is beginning to address these issues.

9 CONCLUSIONS

The AECO industry is finally beginning to use IT, BIM and virtual buildings more effectively. Virtual building *environments* are a strategy to spread the use of this technology throughout the industry. A VBE provides opportunities to organizations in the industry to get help: a structure (an organized way to do it), software, facilities and experts who can guide

the work related to building information modeling and virtual buildings required by “real life” industry projects

It is now up to industry organizations to bring their projects to VBE centers and take advantage of these opportunities. The VBE Initiative represents the beginning of a global VBE network that will hopefully help the entire industry take advantage of the new technology. That will lead to different sets of industry processes, thorough *testing before building*, and (eventually) much better designed, built and working buildings.

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