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The Benefits, Obstacles and Problems of Practical Bim Implementation

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Abstract

The rapid development of Information Technologies in Architecture, Engineering and Construction Industry (AEC), as well as in Architecture, Engineering, Construction and Owner/Operator (AECO), are consistently changing the definition of Building Information Modeling (BIM). BIM technology takes new meanings, highlighting the generic concepts of this universal determination for product deliverables build on usage of building intellectual 3D virtual model associated with this processes like project inception, design, evaluation, construction, operation and demolition. In his article, the authors review the stages and trends of BIM concept development presenting the case studies of four real projects in which elements of BIM technology have been adopted by project participants reviewing benefits as well as obstacles and problems of practical BIM implementation providing recommendations for future applications of BIM.

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Keywords: *building information modeling, product lifecycle management, virtual project development, case studies, practical implementation.*

1. Introduction

The BIM (Building Information Modeling) can be treated as advanced evolution of CAD (Computer-Aided Design) and implementation of BIM technology will contribute to greater construction industry efficiencies through increased collaboration between different project participants, less collisions and repeat work on corrections and adjustments [1]. Extensive research and development in academia and industry has brought many powerful and practical building information modeling tools for analysis, design and detailing [2]. These Digital Construction (DC) tools can be adopted by big or medium size design companies and are in use separately for solving different tasks, however software tools alone are insufficient for efficient BIM implementation [3]. Drastic changes in term of work practices, staff skills, relations with client and participants of project implementation team as well as contractual arrangements are required in order to have successful BIM implementation [4]. Practically project teams consist of members with different level of BIM methodology knowledge. Therefore, BIM implementation process must break some borders and overcome obstacles of different nature. The obstacles are greater in small markets, where design and construction companies are small and have not enough resources to obtain and maintain theoretical BIM methodology.

We will bring practical BIM implementation case, performed in environment with very low level of BIM methodology knowledge and high wish of project team members to work traditionally (without BIM). The case relates to the experiences gained by one team of BIM technology users in four projects with different contractual and management environment. The information collected by the team enabled as to form some practical recommendations for BIM implementation plans.

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2. BIM evolution and development

The acronym BIM at different times describes various things and it still has no single, widely accepted definition. BIM concepts go back to the early days of CAD in the 1980s, being described conceptually by researchers [4] and being implemented in working software in early CAD programs. In that times BIM actually meant building‘s graphical three-dimensional model (3D) enriched by additional intelligence (information associated with graphics). The base of this technology is made up of the Graphical Information Model [1], covering the geometrical model building, its physical properties, names and functional peculiarity of its components. The modern definition of BIM has appeared in late 1990's - early 2000's, with the emergence on the market of a number of SBM (Single Building Model) realization concepts offered by different CAD software vendors, such as Revit, Autodesk, Graphisoft and Bentley [5]. The BIM has become the standard definition of information modeling technology in construction industry when achieving maximum integration (continuous chain of tools) between different disciplines, creating a model of intelligent parametric objects and the first mass implementation of BIM in design companies has begun. Over the past years, consistent effort has been made to provide traditional three-dimensional BIM with "fourth" (4D), "fifth" (5D) and even “sixth” (6D) dimensions, developing on its base PLM (Product Lifecycle Management) analogue for construction industry [3-4], [6]. This solution has a special definition named BLM (Building Lifecycle Management) or theoretical Unified Project Management (see Fig. 1) [7]. This trend has logical idea of further use of high-capacity information stored in intellectual 3D building model.

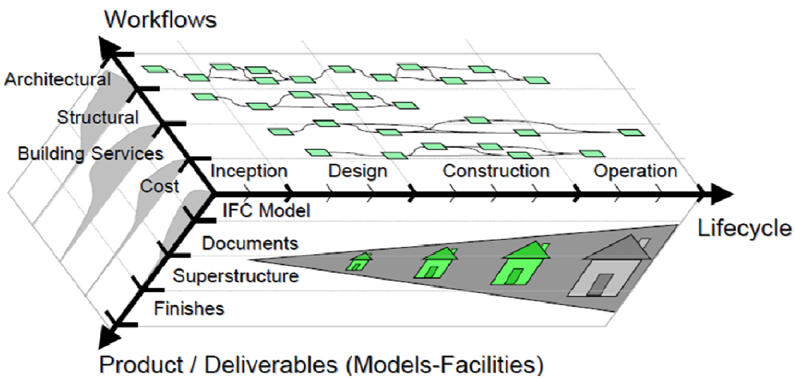


Fig. 1. Schematic of dimensions in Unified Project Management

Summarizing all mentioned above, the BIM may be described as the way: a) to develop the strategy of building project design, construction, and facility management based on the computer-aided modeling and simulation technologies of the object and its development processes; b) to ensure the integrated management of graphical and information data flows combined with descriptions of process, all this performing under the integrated software environment; c) to transform individual executors into teams and decentralized tools into complex solutions, to integrate individual tasks into processes; d) to perform life cycle operations of a construction project faster, more effective, and with lower costs.

3. The BIM implementation – Case Studies

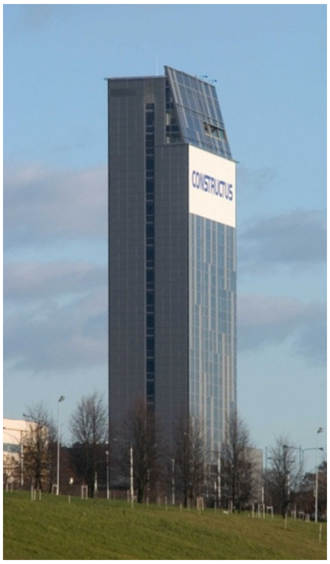
The scientific research and analysis have been made in four projects (in Lithuania), where BIM elements were implemented by the same team, but in different contractual and company ownership environment [6]. The first project was done by construction company with responsibilities of the “design-build” contract. Company owners had policy of the BIM implementation. The final result of the project BIM plan was facility management program with some BIM methodology elements. Three other projects were made, after company ownership has changed and major shareholders stopped BIM implementation program on the company level and those projects had BIM implementation plans on the project level mostly based on Construction Management at-Risk (CM@R) or Design-Bid-Build (DBB) contract.

3.1. Vilnius Municipality (2002-2004)

INFORMATION. The General Contractor start construction works of Vilnius Municipal complex in 2002 and finished in the first quarter of 2004. The 15,060 sq. m Vilnius Municipal complex, comprising a 20-story, 76.85 m (252 ft.) tall main building and adjacent 5-storey and 3-storey buildings, provide space for over 1,000 employees, see Fig. 2. The new Europe

Square, 4,800 sq. m in size, connects the Municipal Center with commercial buildings and the new Vilnius County building, which has also been erected by same company. An 11,500 sq. m underground garage for 344 vehicles has been built under the buildings. The project Vilnius Municipal Center achieved the award - Lithuania Product of the Year 2004.

a)



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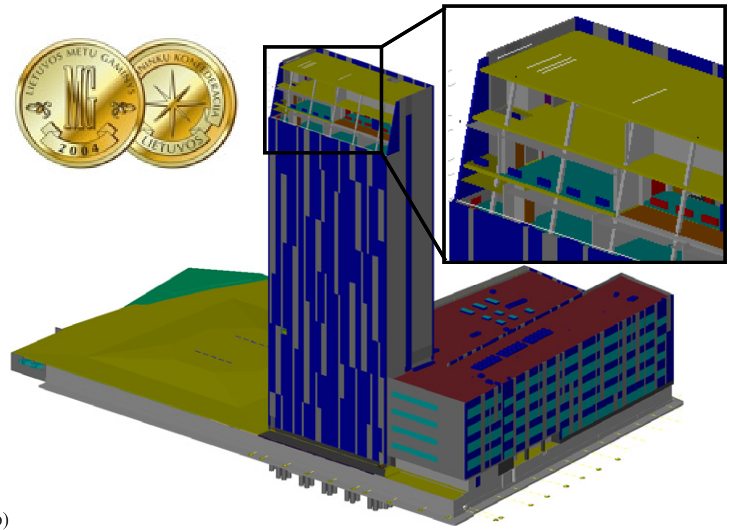


Fig. 2. The Vilnius Municipality in real photo (a) and virtual BIM model for Facility Management (b)

CHALLENGE. Some 10,700 sq. m of glass were used for the facades of the Center's buildings, glazed with high-quality SUN GUARD shatterproof and energy-saving multiple panes. Modern engineering systems have been installed in the new Vilnius Municipal Center. One of Contractors' main tasks was to ensure that the new Vilnius Municipal Center would meet all the necessary criteria in terms of quality, durability and cost-effective operation of the buildings.

SOFTWARE. During the design and pre-construction phases, the attention was paid to the efficiency and functionality. Conceptual design, visualization, working drawings and material specifications were generated from 3D model. 3D model was made using Bentley Triforma and Bentley Structural software. Structural analysis and design was made in STAAD.Pro analysis software using 3D model imported from Bentley Structural (workshop design). 3D model was exported to Bentley Navigator and data concerning with construction of Vilnius Municipal Center were stored in data base using for further project Facility Management. Every element of Vilnius Municipal Center 3D model was connected with information, design and working drawings, production process and contractor company, conformability with certification, maintenance rules and manuals, technical specifications and etc. (for the first time according to BIM theoretical background).

WORK. On average, more than 200 workers were present daily at the construction site of the new Vilnius Municipal Center, and nearly 130 subcontractors and suppliers regularly delivered services and products. Strictly regulated and accurate monitoring of construction processes by construction management (CM) team and special attention to occupational safety requirements helped eliminate risks and avoid even minor accidents. There was strict compliance with all environmental protection standards during construction of the Vilnius Municipality Center.

BENEFITS. Availability to use single prepared 3D frame model for: visualization, structure analysis, final adjusted 3D model and Facility Management model with related information. It was saved ~20% of time for plan and view drawing with AutoCAD and time for redrawing with mistakes correction when changes occur. The 3D model was used for estimation of the bill of quantities for most of work packages, that made easier negotiation process with subcontractors and suppliers. In general the procurement and supply of manufactured elements and details was improved essentially. The personnel time wasted for disputes about volumes of works done during work acceptance phase was decreased and specialist could pay more attention on quality of performed works as well as got time to discuss how to improve methods of work.

3.2. MG Valda Victoria office building (2004–2005)

INFORMATION. In 2005 contractor finished works on the new Victoria office block in Vilnius located in the Business Triangle on the left bank of the river Neris, the 16-storey, 76.3-m high building offers total floor space of 6,500 sq. m.

CHALLENGE. In the course of the competition for the project, contractors' specialists actively sought out technical and technological solutions that could improve the quality of the building and save the customer money. Contractors experts also offered a solution unique to Lithuania: substituting prefabricated, reinforced concrete slabs for a more expensive and time-consuming roof made of steel beams, thereby increasing the reliability of the structure and reducing construction time.

SOFTWARE. New approach in this project was parallel comparison of design in ordinary way and 3D modeling, This solution to test advantages of 3D modeling takes additional working time but it was worth it. Project team was supported with early information about missed design solutions and possible arising problems. 3D modeling with Bentley Triforma and Bentley Structural shows both the correctness of technical project design and workshop drawings. 3D model was used to generate quantities for tendering procedures and analyze comparing the amounts of actual amount of the works. Developed CAES (SAS) – a computer-aided evaluation system in construction, based on BIM concept interconnects structural design, cost estimation and scheduling [3], see Fig. 3. The main purpose is to provide the computer-aided evaluation of the economic criteria of the project design, thereby providing the user (designer, CM, contractor or investor) with the possibility to evaluate economic expenditure (estimates) at any stage of the project. The construction company ensured that this construction had minimal impact on staff in neighboring buildings and avoided unnecessary noise and traffic congestion during the project. Operative planning and management of construction process was another reason to use 3D model for this project. 3D model connected with project schedule (see Fig. 4) "Microsoft Project using Bentley Navigator was mean of construction project management.

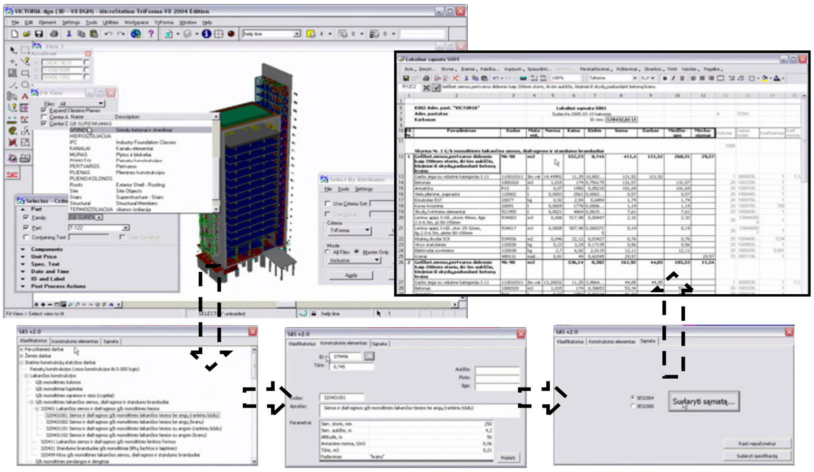


Fig. 3. The way of getting estimates from parameterized BIM model of MG Valda Victoria office building

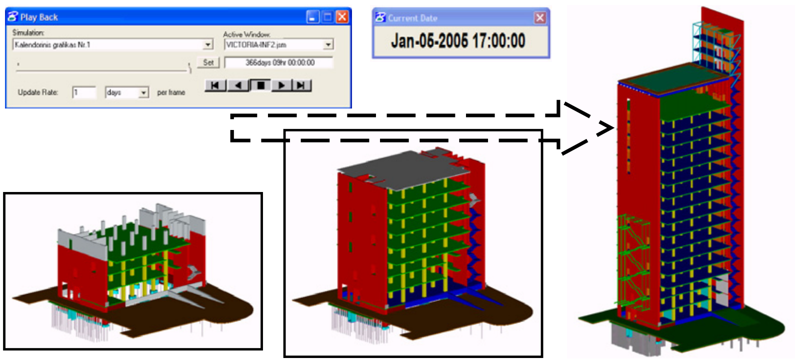


Fig. 4. The BIM model of MG Valda Victoria office building connected with time schedule

WORK. Construction of the office building began in January 2004 and was completed in early 2005. The project demanded that construction management (CM) team experts were extremely precise, meeting all quality and environmental requirements and properly managing the various risks arising in the course of construction.

BENEFITS. The early information about missed design solutions and possible arising problems help to eliminate delays, time saved by project team during construction works and early problem recognition influence the construction quality and fast handover process. Construction site manger and project manager have saved about ~10% of there time to look for problems. The BIM technology made was very helpful during planning and managing construction processes and materials delivery to site in very tight construction site with demanding neighborhoods of office workers.

3.3. PET plastic raw material plant in Klaipėda (2005-2006)

INFORMATION. Construction management team had little time to make a decision when client – a leading manufacturer of PET preforms and plastic bottles in Central and Eastern Europe – presented its investments plans to CM team and proposed that CM team sign on as a construction partner. The project PET plastic raw material plant in Klaipėda achieved the award – Lithuania Product of the Year 2005.

CHALLENGE. CM team would have to break all records and construct the factory in a little more than 1.5 years. CM team had to ensure that our client's production process would begin on time, because every day of delay would, mean great losses. The first task was to identify and measure risk, but this was followed by an even more important undertaking – to create a strategy and forecast the appropriate tactical actions to manage it. Having immediately mobilized the construction team, CM team began implementing the project structure and schedule and carrying out construction preparations.

SOFTWARE. During construction preparation works preliminary 3D model frame of “matchbox sticks” were made with Bentley Triforma. Combining 3D model with project schedule in Microsoft Project gave possibility to analyze complex construction works and divide it in stages and both independent and synchronized work areas. After analysis of several construction simulation alternatives the construction works were arranged to complete works in time. After load arrangement and structure selection, design works started and the detailed 3D model was made which was used and several times corrected during project implementation, see Fig. 5. 3D model was used as control mean then CM team gave it to Client for comparison with technological processes 3D model designed by the German company.

WORK. All construction and technology installation work for the PET raw material factory were entrusted to CM team – manage preparation of the detailed and working drawings and construction works of all main production buildings as well as all service buildings, territory and infrastructure works, technology installation works. The project proposal was prepared by the design company of Lithuania together with CM team professionals. Technological processes and equipment for the factory were designed by the German company, a supplier of polymer production equipment. It was decided to make construction works of the main polycondensation and polymerization block in 4 stages and execute works in 3–4 synchronized work areas. Construction element supply and installation works were managed according synchronization points of project schedule and no delays were allowed.

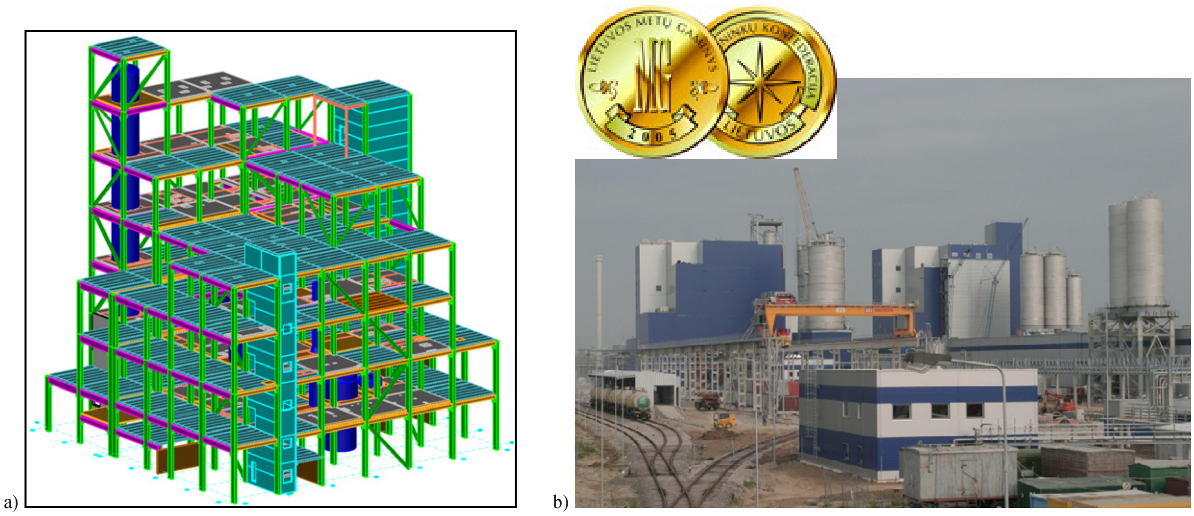


Fig. 5. The “alive” BIM model of KLAI-PET with technological equipment (a) and photo of the finished factory (b)

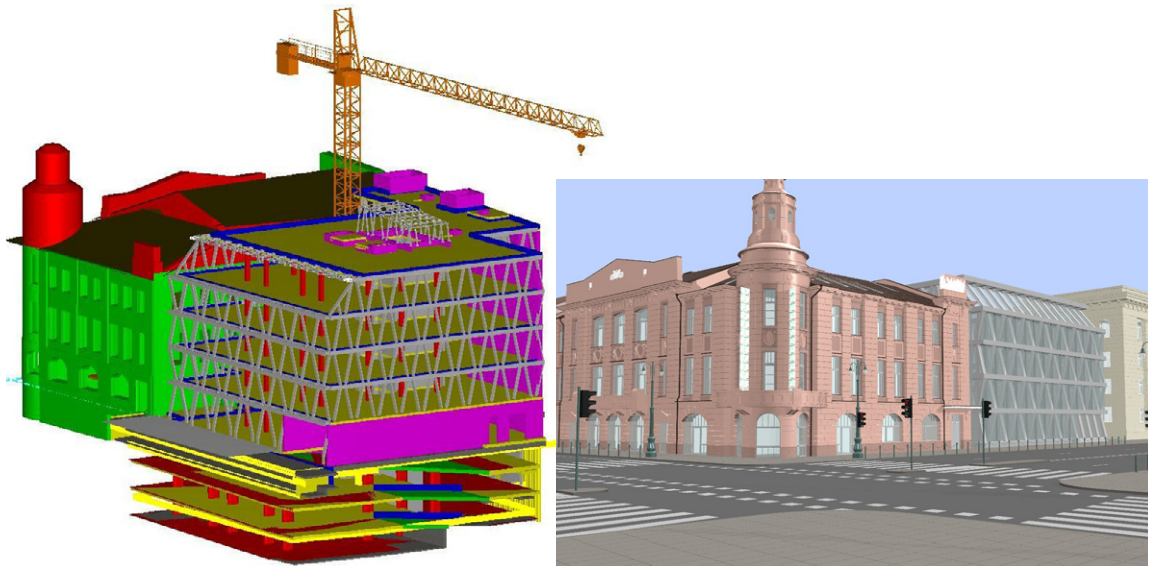
All even minor changes in supply and working schedule were simulated in “Bentley Navigator” to see influence on synchronization points and to make process control actions because the probability of mistakes is very big then this kind of works are done multiple times. Managing this demanding work flow not only required CM team own experience and skills, but those of a huge team. At the peak of construction there were more than 1,000 workers on the site, including more than 20 suppliers and subcontractors. The most technologically complex building is the main polycondensation and polymerization block, which occupies an area of 12,500 sq.m and is 50 m high. About 150 repositories were installed and two core reactors were assembled there. At 4.8 m long and weighing 125 metric tons, one of the reactors was shipped from Germany on a special barge and was later hauled from the port of Klaipėda on a special truck with an nearly 20 m long 13–axle trailer. CM team professionals hired a special crane with a 500 metric ton lifting capacity from a partner firm in nearby Estonia, as there are no cranes in Lithuania with such lifting capacity. The crane lifted the reactor to a height of 14 m.

BENEFITS The BIM 3D technology at first was very helpful tool during design as main tool for technology and construction drawings coordination, that enabled CM team minimize time consumption for redoing and corrections. It also enabled to define critical points and areas from structural and technology point of view in advance and to have critical work preparation done in time. The work packages quantities generated from the BIM model minimized "Human nature" mistakes in orders of the materials and products needed at strict time. The economical benefit of system used and savings gain by selected solutions and accurate bill of quantities exceeded not less then 10 times extra management costs for use of BIM methodology. Virtual Project Development (VPD) was used as a 3D model for simulating the construction process and virtual work implementation management which should be performed in advance to avoid possible collisions of cranes and structures [6]. After opening the first production line in October 2005, the owner of the plant, chose same CM team for further development of the plant. The company have used experience of project management using 3D model from first line and complete all the newly agreed construction, technology and pipeline installation within six months.

3.4. Office building at Gedimino ave 35 in Vilnius (2008–2012)

INFORMATION. In 2008 construction management company started refurbishment works of administrative building in heart the Old town of Vilnius. The old building on Gediminas ave 35 was build almost 100 years ago (1913) and belong to Cultural heritage of Lithuania. The design has been made to build Office building as the complex of new office and refurbished old administrative building, see Fig. 6. Total area of office building is 10,200 sq. m., it consist of 3-storey underground parking for 2900 sq. m., 4-storey old and 5-storey new building for 6300 sq. m. of lease able area.

CHALLENGE. The main challenge was to ensure effective collaboration between different project participants, disciplines and software. Interoperability and project participant collaboration for project implementation was main issue due distant design works: architect in Germany, design of structure and HVAC in different parts of Lithuania.



a) b)

Fig. 6. The BIM model of office building in Gedimino ave 35 with 3D crane for structure installation works and architectural visualization

WORKS. The underground structure (half of 3-storey was under ground water level) is from cast-in-situ concrete and the over ground building structure made of external load bearing steel frame interconnected with concrete structure (special anti thermal bridge elements were used ensure energy efficiency).

SOFTWARE. Nemetschek Allplan Architecture – architecture and visualizations; Bentley Structural – 3D structural modeling, Nemetschek SCIA Engineer – structural analysis and design; Nemetschek Allplan Engineering – detailing of reinforced concrete structures, drawings, BOM; TEKLA Structures – detailing of steel structures, drawings, BOM; AutoCAD & CADVENT – HVAC and pipe systems, the intents to connect all design parts were made using Bentley Triforma platform. 3D PDF in Adobe Reader was used for design improvement (clash detection) and collaboration with both participants and the client.

BENEFIT. The effective usage of BIM technology helped to check interoperability between design disciplines save about 0.5% of project value in workshop design stage. Acurate bills of quantities enabled to minimize overpayment for suppliers at same time relations between CM team and subcontractors and suppliers were cooperative, without unnecessary disputes and with motivation to look together for better solutions.

4. Benefits, limitations, obstacles and problems of BIM

In 2007 the Associated General Contractors of America (AGC) published the AGC *Contractors' Guide to BIM* [8]. It was based on contractors' experiences, general beliefs and advices about BIM implementation. The guide was updated in 2010 with information on the process of incorporating BIM into AECOO company, collaborating with other project participants as well as a detailed matrix of the varied types of software tools that comprise building information modeling. The main objective of the guide is essentially to educate all project participants about BIM, including its benefits, tools and applications. Also with giving the clarification of the fundamental responsibilities of each team member relative to the BIM process and description the main areas of risk management [5–6], [9]. From the perspective of design document's quality, the user of the BIM can improve the coordination between the documents, disciplines, and across the entire team or project participants, reducing the number of errors and omissions. With the coordinated design documents and well-captured design intent, the enhanced process of design makes for a far more informed design environment and save resources (not limited to materials, money, time) in project implementation [3].

As representatives of AECOO industry researchers and professionals working with BIM implementation, gave their opinions about BIM-based process in multiple analysis, reports and scientific works. The aggregated thoughts and results of real benefits, limitations, obstacles and problems of BIM implementation (experience for almost two decades) are given below [1], [3], [5–6], [8–10]:

- Mostly project participant are used to work with particular tools (software and hardware) and often data transfer is limited due incompatibility and transmission of the consistent information to other participants. The not transferred data need to be recovered and extra efforts need to be made to do it or add the information for other particular tools;
- Project participants are making use of intelligent models for parts of the project scope to assist them with of their traditional activities (not limited to design, time and cost evaluation). Mostly it is focused on the scope of work that was most expensive or that appeared most risky and need to be evaluated in details based on reliable source of information;
- Implementation of some intelligent approaches as Virtual Project Development for the first time in the project and mistakes shows the lack of experience and leads to time consuming searching activities or expensive consulting with market best practices. Mostly the virtual background and prepared models are treated as superficial and not trust worth.
- Getting the maximum benefits from the BIM technology is directly correlated to the ability to maximize collaboration in project. No matter who is leading, then all key participants are involved offers most benefits for the whole project team;
- To use BIM effectively, the project must be delivered with collaborative approach (as it is common to use 3D/4D models) such as in Construction Management at-Risk (CM@R) or Design-Build (DB) projects. However, experience has shown that there are still specific benefits in traditional Design-Bid-Build (DBB) projects;
- There are many barriers keeping project participants from using the latest technology and BIM. The barriers include fears of too low success low or big failure, high initial investment costs, the time to learn how to use the software, and perhaps for many the biggest barrier: the lack of support from senior leadership of the company (conservative approach);
- To carry out 4D modeling in an efficient way, the knowledge what 3D/4D modeling software to use and the limitations of 3D/4D modeling software tools and information management and issues stemming from data exchange and effective hardware to use and both the organizational and professional qualification alignment need to be resolved;
- The last but not the least obstacle in BIM implementation is the lack off information about the strict BIM implementation standards and rules for certain project participants, contract obligations in certain countries or unified documentation for regions (such as European Union, Americas, Asia and other).

Which problems prevail during project implementation depends on contractual arrangements (system of contracts and imfluence of contractural environment in every country) of the project delivery, because those arrangements forms general atmosphere of the project participants relations climate. The contractual arrangements of lump sum contracts between CM team and client and back to back between CM team and suppliers lead to environment, where each member of project team gives priority to its individual interests not to common project goals. Therefore, all problems mentioned above will be in place, that will born huge barriers for BIM methodology implementation in full scale, and in this case only partial BIM technology elements can be used by separate participants needed for fulfillment of they work package [6]. On contrary integrated project delivery (IPD) contractual arrangements lead to minimization of mentioned above problems and to best environment for full scale BIM methodology use and best conditions to collect all benefits of BIM theoretically. The IPD with BIM methodology creates value added and most of benefit to the final user (public society, owner of the buildings or tenants) of the build environment.

5. The conclusions

The information and data collected in all those four cases enabled us to determine productivity and profitability gains as well as learn experience of the BIM implementation team. The experience of project participants as the team allowed as to define process of the decision making before start of the BIM implementation in separate projects as well as to make recommendation about BIM process planning in the environment of small companies with different software and methodologies of works.

The BIM implementation requires urgent development of the reliable tools for information exchange between different software tools at same time enabling efficient and direct coordination and monitoring processes between project participants and team members, employed for the project from different companies and using various tools as software sets.

For more acceptable BIM implementation, the acceptable level of interoperability and standardizing the work methods must be prepared for project participants and team members.

The BIM technology and tools are developing rapidly (based on basic BIM methodology), but their effective and fast use in the practice are constrained by existing contractual arrangements and traditional organization in the projects directed by stronger party with atmosphere of fights for individual benefits instead for search better project delivery solutions and alternatives, which can make participation in the project delivery beneficial for all involved.

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