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# Traditional Design versus BIM Based Design

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**Abstract**

The paper shortly presents the history and development of the traditional design in civil engineering. Next, the idea of Building Information Modelling (BIM) and its practical benefits are described. Main part of the paper is devoted to discussion about what kind of difficulties we may encounter during the implementation of the BIM technology and how they are related to the potential benefits. Case study presents the existing design prepared in BIM technology.


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*Keywords:* traditional design; civil engineering; CAD; BIM

## 1. Introduction

Designer's work has changed over the last decades dramatically. For many centuries designers have had at their disposal only sheets of papyrus, paper, ... .ink, and simple abacus. Classic methods of structural design have been developed for centuries and remained unchanged with time. An architect (builder) was (and still is) responsible for the entire investment project, and could be considered as "a walking database" containing all approved information as well as information about identified collisions which has to be solved.

In the second half of the 20th century architects and engineers have stopped to use traditional drawing and calculation tools. Currently, the most commonly used tools by the design engineers are CAD / CAE systems. However, the next step called BIM is coming fast and wide front.

Development of CAD design software has been an evolutionary process. On the one hand, the development of the automotive industry enforces increasing optimizations of the construction of vehicles. Similarly, the aviation industry demanded aircraft design ever lighter, streamlined, and consuming less fuel and flying longer distances. Only the use of increasingly accurate computational methods as well as development of computer graphics (2D and 3D) enabled to give up very costly laboratory experiments in small-scale models or full scale tests.

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## 2. Traditional methods of designing with the help of CAD systems

Architectural and engineering design is a task for large teams consisting of specialists, such as architects, constructors, installation engineers, quantity surveyors, project managers. For many centuries the basis of the projects were (and are) 2D drawings (plans, sections, elevations) of designed building in a symbolic manner, in accordance with the principles accepted by all participants in this process. Usually the architectural concept is fundamentally different from the final design and structural design. Architects mainly use sketches of bodies (3D elements shown in perspective) whereas civil engineers - plans or details drawings. Another source of confusions or mistakes are two types of plans: architectural projection shows what is below the cut surface, which is usually located at a height of 1 m above the designed floor, as an architect is interested in the layout of the designed story. In contrast, a building (construction) plan shows what is under the ceiling of the floor considered by architect, since constructor is interested in the substructure supporting the floor considered by architect.

In the classical method of designing each of the specialists work on separate industry drawings (prepared on tracing papers) with only those elements for which they are responsible. Tracing papers produced by specialists are imposed on each other during the coordination meeting to check the compatibility of the project.

CAD systems modernized the process. Instead of tracing papers the separate layers in the CAD program are used by each of the specialists. However, designer works in CAD on plans of the same building and the interdisciplinary collisions (e.g. structure-installation) are inevitable. The coordination meeting and correspondence are devoted mainly to solve the conflicts. Use of the CAD systems makes this process easier although it is time consuming and not always successful. When on one layer with installation something is changed then quite often it is not on 2D drawings not only with plans, but also with cross-sections or elevations, which should be changed both in architectural and structural design.

In parallel with CAD software CAE systems have been developed to support the calculation of the structure. Special programs have been developed for installations. Nowadays functionality of available CAE programs is very high - starting from simple programs for static or dynamic analysis of specific elements or structure, including checking the requirements specified by standards. Complex calculation systems (such as Autodesk Robot) collaborating with CAD/BIM systems are developed steadily. They allow for comprehensive modelling of the structure, the load patterns combination module supports thousands of different variants. Final results of analysis can be easily transferred to CAD/BIM systems in order to adjust the 2D/3D model and produce structural drawings (dimensioning and reinforcement drawings, detailed design of steel connections etc.).

## 3. BIM based design

### *3.1. Definition of BIM*

Acronym BIM is translated in two ways: either as Building Information Modelling or Building Information Management. American Committee of the National Information Model Standard Project Committee defines BIM as "*a digital representation of physical and functional characteristics of a facility...and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.*" (buildingSMART, 2010). [1]

U.S. Government General Services Administration defines BIM as "*the development and use of a multi-faceted computer software data model to not only document a building design, but to simulate the construction and operation of a new capital facility or a recapitalized (modernized) facility.*" [2]

Another document issued by British Standard Institution *Specification for information management for the capital/delivery phase of construction projects using building information modelling* (PAS 1192-2:2013) defines BIM as "*the process of design, construction and use of the building or facility infrastructure using information about virtual objects*" [3]

In 1962, American engineer Douglas C. Englebart described his vision of an architect work:

*"(…)the architect next begins to enter a series of specifications and data–a six-inch slab floor, twelve-inch concrete walls eight feet high within the excavation, and so on. When he has finished, the revised scene appears on the screen. A structure is taking shape. He examines it, adjusts it… These lists grow into an evermore-detailed, interlinked structure, which represents the maturing thought behind the actual design."* [4]

Above description is a very good characteristic of the essence of BIM.

### *3.2. Levels of BIM*

BIM is based on a virtual 3D model of the proposed facility as the sole source of all information about the project. According to the diagram by Mark Bew and Mervyn Richards [5] four Levels of design based on CAD and BIM can be distinguished. Level 0 contains any kind of paper documentation, created by hand or with the aid of CAD programs. Level 1 concerns documentation 2D and 3D in the form of digital files without use of a detailed database. The next Level 2 can be considered as the starting level of building information modelling. It seems to be quite similar to earlier Level 1. The key difference is the library management and file based collaboration used in the project.

Thus, the essence of BIM is a shared database for the project, assigned to the 3D model of the object, based on which we can build a complete project documentation. Currently, most engineers work somewhere between the Level 1 and 2. Promoters of BIM put a target to prepare all projects in BIM at Level 3 - intelligent BIM (iBIM), which makes construction management possible throughout life cycle of the design. Moreover, they expect the introduction of ISO standards and widespread use of BIM formats, e.g. IDM, IFC, IFD.

## 4. The use of BIM - the benefits in practice

Building Information Modelling is the next step in the development of computer-aided design. In practice, instead of several specialized documentations containing architecture design, landscape design, construction and installation designs as well as bills of quantities and cost estimates, we have one 3D model with a database containing all above information. Parametric modelling is the essence of the full application of BIM in practice. It allows quick implementation of changes in 3D model when it is necessary during the interdisciplinary coordination process. Other benefits of using BIM can be distinguished. They are shortly described in the following sections.

### *4.1. Collision detection*

Collision detection is the essence of interdisciplinary coordination in the traditional design, where collisions have been identified with help of overlapped designs on tracing papers in order to find out visually all intersections. CAD 2D systems make use of the similar approach - layers in different colours are visually compared on the computer screen. Next step - CAD 3D model made it easier to detect collisions. However, there is an important difference between CAD 3D and BIM 3D. Collision detection in BIM is based on algorithms developed in gaming industry and computer graphics. BIM collision detection algorithms should be more exact rather than fast. Therefore, BIM systems make use of computer graphics procedures as well as good standards and engineering practice.

Collisions detected by BIM can be divided into three categories:

- Heavy collisions - two elements occupy the same space.
- Light collisions - free space (clearance or tolerance) needed for assembly of installations.
- Technological collisions - checking the assembly sequence and delivery schedule; checking number of workers and time needed to complete the construction phase.

In general, the collision identification is regarded as a major advantage of building information modelling. It allows for saving significant costs both during design process and during works at site.

### *4.2. Dimensions of BIM*

Depending on the content of database we can distinguish higher dimensions of the BIM approach.

**BIM 3D** - Virtual 3D parametric model - nowadays accepted by designers as a natural extension of the 2D design.

**BIM 4D** - Scheduling - denotes BIM 3D model extended with one extra variable - time. Tedious scheduling is replaced by parametric modelling, in which every element is assigned in a sequence of assembly. BIM 4D creates new opportunities for information modelling: the division of the project into phases, visualization of phases, simulation of schedule of works, accurate planning for delivery time of products and materials.

**BIM 5D** - Estimating - means BIM 4D extended with another variable - the cost of labour and delivery for each item. BIM 5D enables fast estimation of cost for conceptual designs and any other cost estimations.

With help of BIM 5D we can easily compare execution time and total costs of various alternatives in terms of materials and technology, what can promote the optimization of the total cost of the investment.

**BIM 6D** - Sustainability - Software compatible with BIM 6D allows for integration of data related to environment protection or energy consumption, i.e. with help of special programs the analysis of building energy consumption is possible. Models prepared in BIM 6D environments are often used as a primary tool to meet requirements defined by LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Methodology).

**BIM 7D** – Facility management application - The database should be extended with detailed information for each embedded element: building (structure), finish (e.g. types of floor) and all equipment (lamps, heaters, etc.). The relevant information is a type of the item, its specification, the time of the next maintenance or replacement, the warranty period, the time consumption. This will allow for convenient maintenance of the building, and when failure occurs, it will be able to be quickly located the item and repaired.

### *4.3. Analysis of concept designs*

BIM model is a tool which radically changes the conceptual phase of design. Analysis of the concept design and trials to find out structural design suitable for architect ideas is time consuming and expensive when using traditional design methods. Each concept had to be examined and manually calculated often with help of simplified methods. With CAD software it is easier to come to conclusions, but still engineers should build a separate structural model for each architectural concept design in order to carry out static calculation and further detailed analysis.

BIM 3D model essentially facilitates collaboration between the architect and the structural engineer. Nowadays, a 3D model prepared by an architect can be relatively easily and quickly converted to the analytical model that constructor can use in the structural analysis. In a few simple steps structural engineer can obtain the stresses or deflections and proceed with detailed checking of code requirements. Furthermore, architect can easily check up the cost for each conceptual design already approved by structural designer.

## 5. BIM in practice - case study

The office complex in Warsaw has been designed with help of the BIM software. The design was divided in two phases, first one consists of a 6-storey and 4-storey segments while the second phase consists of two 4-storey segments. The complex comprises more than 30,000 m sq. of office space. Sustainability was an important factor during the designing process. Ergonomic lighting and air-conditioning (incl. climate convectors) was designed. Erected building would be tested for BREEAM certificate with an aim set on 'very good' result.

The project has been prepared and carried out with help of REVIT system. In the designing process 10 designers were involved at the same time. In general, the design process has been estimated as 10% faster and 80% more accurate than the traditional designing method. Only three people – leaders in each industry (architecture, construction, MEP) – had relevant experience in using BIM method. The rest of the team was introduced to the technology. Proper leadership resulted in no significant loss in productivity.

The 3D model was divided in two parts – MEP and architectural-construction.

The whole data coordination was conducted on the BIM model, no traditional designing method was used and what is more important – CAD files were secondary. Collisions were detected in Autodesk Revit during the model coordination. The whole team was meeting and every issue was solved in a conference room with the use of a projector and the model. Some BIM browsers were used – especially Autodesk Navisworks.

Although tasks were accurately assigned, the main coordinator was the general architect - as in traditional approach. He was co-responsible (with MEP and construction leaders) for Revit operations, such as co-creating the model and implementing changes.

A standard model synchronizing scheme, provided by Revit, was chosen. A central file was located on company's central server and local files were located on PCs. Files were synchronized every 30 minutes on average. However, the more details has been put in the model the more frequent the coordination has taken place.

The construction site was provided with a traditional paper version of the documentation (as the Polish Law requires) as well as with the BIM model, which was effectively used during MEP installation process.

All collisions were eliminated in the designing phase and no clash appeared on the site.

Concluding, during the designing process fewer re-designs, processing, revisions and changes were found. The total cost of BIM implementation paid back with accurate ordering of materials and elements. Quantity of materials was consistent and there were no unnecessary or incompatible elements.

In such a large project case the total amount of time needed to produce the documentation has decreased by around 30%. Such result was possible thanks to working on one model rather than on several dozen of different CAD files. Time saved on drawing was used on coordination and elimination of clashes in the designing phase.

## 6. Is “the best enemy of the good”? – drawbacks and merits of BIM

An undeniable merit of the classical designing method, aided by various CAD and CAE tools, is that the most experienced designers have applied this approach for many (hundreds?) years. Classical design method is doubtlessly the best one with respect to small and medium sized projects – with its cheap cost as a main advantage. However, successful implementation of classical designing method demands well-educated designer. He firstly got to graduate from university, then to perfect the designing skill and method and subsequently he should gain experience on the construction site or as a member of the design team. Of great importance is also on what kind of projects the designer has got practice – size of the projects, their diversity in terms of technology, materials and products. Leading architect or constructor are project information managers. However, coordination problems appear as the information may be incorrectly understood or interpreted by designing team members. Another source of collisions, unsolved in due time, may be schematic documentation, which has not been changed according to coordination meeting decisions.

In many aspects, in comparison to classical designing method, BIM technology is unrivalled, since BIM project fully integrate all information what results in better interdisciplinary cooperation, quick and easy project updating, and also positively affects clash detection, bill of quantities and cost estimations.

Nowadays BIM is the most complete method for building design and facility information management.

According to aforementioned, a question arises: why does the usage of BIM in the everyday practice encounters so many difficulties? Although BIM has an undeniably huge amount of merits the technology is not flawless, and some of its drawbacks cause difficulties in implementing it as an everyday-use designing method in Poland.

**Problem No. 1 – High implementation cost**

The first and foremost the high cost is caused by huge hardware and software prices. Software of full functionality just for one working place cost around tens of thousands PLN (Polish Zlotys). Additional expense is the hardware cost, which vary up to several thousand Polish Zlotys per workstation. Server and backup cost should also be included. Summing up, the total cost per working place for BIM operator is estimated at 50 thousand PLN (Polish Zlotys). Taking into consideration the fact, that one person is not able to model the whole structure, installations or architecture – the aforementioned price should be multiplied by several working places, according to the needs of the designing office. Costs counted in hundreds of thousand Polish Zlotys or Euros cannot be easily spent by each and every office – especially in such hard times for construction industry. It is the high cost of implementation that blocks it in small and medium designing offices.

**Problem No. 2 – Designer’s education cost**

With respect to education of designers it should be noted, that the effectiveness of the team work is determined by quality and efficiency of work of people who either do not know BIM, or have never worked in a team. In extreme situations a great loss in productivity is about to appear, as well as delays due to designer’s ignorance of the designing tool. After several weeks an engineer or architect should be able to use the designing program properly and to create a simple model. However, the investment in staff training on a high level (several steps training) is expensive and would pay back when the total BIM technology is fully implemented in large projects.

**Problem No. 3 – Accuracy – a plus, that could be a minus**

Virtual representation of a designed building is modelled with 100% accuracy not often met in everyday practice. Construction industry used to operate on schemes and symbolic drawings rather than on the exact virtual model of building. The construction process enforces final and accurate decision to be taken. BIM model requires accuracy in modelling from the very beginning. Strict standards and rules have to be set within the team to work according to BIM standards, as this affects the whole designing team work and its efficiency. BIM technology requires from the members of the design team to abandon the individual working schemes, so characteristic for each person and specific for discipline or design office. BIM 3D model - exactly following the architect idea and coordination provisions - is the key for project to be done correctly. Even the smallest mistakes in modelling either objects’ parameters or construction elements’ hierarchy can lead to major miscalculations and result in major faults and designing complications. In such situations great engagement of experienced designers, architects and MEP designers in both designing and erecting phase is a key to implement BIM properly.

**Problem No. 4 – BIM terminology in contradiction to up-to-date jargon**

Building Information Modelling - as a new approach - requires participants to get to know with vast array of new expressions, phrases, nomenclature and jargon that is unknown for people who worked with CAD software used in classical designing method. During the transitional period it can lead to different interpretation and even misinterpretation of tasks and facts – resulting in faults in project.

**Problem No. 5 – Only complete BIM model is useful**

Nowadays technical building documentation (2D and on paper), following the law regulations, should be prepared from 3D model. In order to prepare coordinated technical documentation of full functionality, estimations and juxtapositions – so in fact to use BIM and its merits completely – the model got to be completed. It means that it is impossible to prepare some of the technical drawings earlier, so that part of the documentation is delivered on the construction site. Thus, the design should start earlier in comparison to the classical method what can result in increasing amount of designers, at least in the first phase of designing.

**Problem No. 6 – Who should benefit from BIM and who should pay for it?**

Division of costs and benefits has to be defined realistically among all sides involved: the investor, designer and contractor. The compromise between these parties is necessary in order to avoid resistance from the party who has to pay the cost of BIM application and would not participate in any of the benefits.

It should be noted that the designing cost can be higher than the designing cost according to classical method standards. However the total investment and facility management costs should be significantly lower. The time of design process could be longer, but the erection time should be reduced.

**Problem No. 7 – Lack of legal regulations**

Today, there is no significant legal regulation regarding the widespread application of BIM based design. That can lead to misunderstanding on the investor-designer-executor line, e.g. in documentation delivery form or model's level of detail. Such conflicts can lead to delays on the construction sites, resulting in additional cost or even long-lasting lawsuits. From the other side lack of legal regulations regarding BIM, e.g. unfair costs and benefits distribution would not stimulate the implementation of BIM method in everyday use properly.

## 7. Conclusions

It is very important to conclude that BIM based design can be effectively implemented in the design practice by experienced designers. BIM allows for simplification of many tasks and considerable savings both in terms of money and time. However, the successful implementation of this technology requires skillful design team who acts exactly in accordance with BIM system procedures. Nowadays, given the high cost of implementation, application of BIM is profitable mostly for large projects. As the software and hardware become cheaper the accessibility of BIM would spread over smaller projects. Doubtlessly, BIM is the most complete designing tool which can change radically the designing process in the following years.

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