BIM as the New Sustainable Design-Construction Manager: Case Study of ALN Building Project Experience

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Abstract Traditional architectural design and practice, especially in the construction process, has evolved into the digital age. The development of the Building Information Management system or BIM has facilitated architectural practice for more than ten years. However, many design practices are unaware of its potential to be more than just a data storage system but also a valuable tool for design management and an indispensable part of the construction process that involves multiple consultative parties such as the engineers, building authority, manufacturer, and others. This paper documents an interview with Markus Neuber in describing the success of using BIM as the new Design and Building Management tool for the future practice and education of architecture. Much of the information is from first-hand experience in design and construction management of the authors. The paper also makes suggestions as future potential of BIM as a Project Manager for the construction process as well as facilitating multidisciplinary approaches to design of buildings.

Keywords Building management · Design · BIM · ALN building · Architecture practice

1 Introduction

The problems in design and construction management has caused an overrun of cost of up to ten times from the initial cost estimation. Most of the monitored projects have a high level of design and building mistakes. Most of the monitored projects suffer from low time-efficiency, huge teams involved and no consistency in any phases of the design and building process. It is suspected that controlling information data

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mismanagement may be the cause of poor design and construction coordination at the level of design consultancy, planning commission authority, and construction phase.

BIM systems have appeared in the scene of the architecture and construction chain by addressing multidisciplinary inefficiencies, incapabilities, disorganizations, and delays that have been rooted in the structure of architecture and building chain over decades. However, German and European architecture and construction chain are having huge difficulties in accepting, endorsing, and understanding the BIM benefits, as there are no clear guidance and best practices in BIM implementation that can be learned by them as a form of reliable examples.

Experience in managing building design projects suggests that BIM involved projects are able to achieve higher accuracy, design quality, team collaboration, and cost and time-efficiency compared to traditional design and build projects. At the moment, there are indications that clearly represent the current low-use and misuse of the BIM software among the teams involved in the building chain. There is a need, therefore, for a more effective Building Information Management system and a properly (advanced) method of use.

2 Literature Review

BIM as a system, in general, has evolved in different stages from Build Description System (1970) to Building Product Model (1980) to Generic Building Model in (1990) till Building Information Model (2000). A worldwide revolution was growing in the accessibility of information. The development and usage of data represented a major improvement in the way information can be discovered, applied, shared, and presented.

BIM, according to the National Standards in Germany of the Modeling Information System (NBIMS), is defined as "a numerical representation of the physical and functional characteristics of an object to serve as a common knowledge source for information on a structure that creates a reliable basis for decisions during its life cycle, from the beginning to the next". Based on the abovementioned definition, BIM is a concept that enables a variety of techniques that link the process of virtual design practice and building through the lifecycle of the project (Fig. 1).

The purpose of the BIM process is to develop models that include information management. This is possible through models that form a comprehensive plan for all participants to share knowledge and communicate regarding the project. The models utilized by the BIM process consist of 3D and 2D animations of building components ranging from design information, materials, manufacturers, and physical location to all components.

The BIM concept has already been accepted in the construction field, but its application and potential values require even more research in order to achieve a more detailed process. Architectural practice is being redefined by the increasing use of BIM technologies, which have been replacing CAD tools at certain design

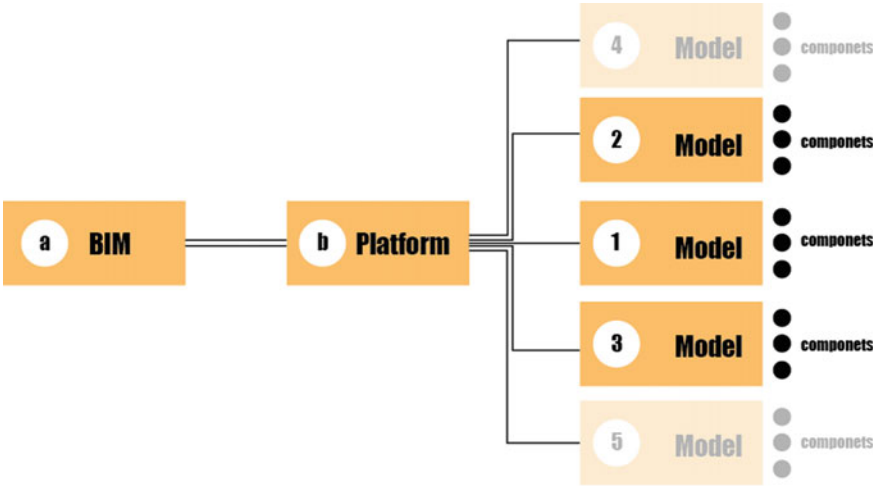

Fig. 1 BIM concept

levels. BIM allows architects to represent buildings' components in their 3D models, containing not only the geometrical information but also the corresponding constructive information. As a result, the obtained models include all of the building's information, which is important for the different specialties, and also for analysis and optimization processes during the design stage.

Initially, most GD tools were developed for CAD environments, but there are already some extensions that allow the exploration of GD inside BIM tools, thus merging the potentialities of both approaches and allowing the emergence of a new design approach called algorithmic BIM (A-BIM).

BIM is perceived as a new paradigm of designing, modeling, and building, but this concept is not recent at all. In the earliest years of computing, in 1962, Douglas C. Engelbart published the paper Augmenting Human Intellect. He described his vision of the future of architecture and presented some of his ideas and concepts, such as:

The next architect begins to enter a series of specifications and data—a 6-inch six-inch laboratory, twelve eight-inch concrete cubes within the excavation and so on. When finished, the revised scene appears on the screen. A structure is taking shape. He examines, regulates it. These lists grow into an increasingly detailed and interrelated structure that reflects the thought of prudence after the current design.

In 1975, a concept very similar to the BIM approach was first documented by a working prototype called "Building Description System". It was published in the AIA Journal by Charles M. Eastman and several concepts of BIM were also mentioned below:

Interactively defining elements, derive(ing) sections, plans, isometrics, or perspectives from the same description of elements… Any change of arrangement would have to be made only once for all from the same arrangement of elements would

quantitative analysis could be coupled directly to the description… cost estimating or material quantities integrated database for visual and quantitative analyses…automated building code checking in the city hall or the architect's office. Contractors of large projects may find this representation advantageous for scheduling and materials orders.

Meanwhile, in the early 1980s, other parallel researches about BIM were conducted in Europe and in the USA. While in Europe, this concept was named "Product Information Models", in the USA it was described as "Building Product Models". Thereon, these two nomenclatures later merged together into "Building Information Model".

The first true BIM software, Radar CH, which later became ArchiCAD, was developed by Gabor Bojar in Hungary. Even though ArchiCAD was the world's first BIM software, it did not become very popular until recent years, due to computing limitations of the time as well as the unfavorable market trends.

Since there are different BIM software in the market, it became difficult to exchange data from different BIM platforms. Therefore, in order to combat this problem, the International Foundation Class (IFC) was developed in 1995. IFC still has some exchange limitation, but it is constantly adapting and improving model exchange. After some years of BIM development, in 2005, the first industry-academic conference on BIM has been held, where a broad range of software designers and vendors, as well as successful BIM tools users, were present, showcasing their individual achievements.

3 Project History

In 2012 ALN/Leinhäupl + Neuber architecture office had an ongoing growing staff, resulting in an increase from 15 to 40 employed designers, architects, and engineers. Thus, there is a great need for a working space that is three times bigger. The management of the office decided to build a new building which would be connected with the old working space. The new building extension included two floors of offices, garages for all the staff and a residential area on the top of the building.

The concept was that this project should be one of the most significant and representative projects for one of the biggest architecture offices in Bayern region in Germany. This was going to be a giant project for the architecture company since the project after calculation needed to have around two thousand square meters and enough room for more than 30 architects.

After the first initial project that took the researcher and other two years of research, planning, and decisions, the company decided to build the building with insulated concrete. Insulated concrete is one of the most ultra-modern materials that engineering uses to build. Building with this material is very sustainable, healthy, economical, efficient in long terms, and has the best quality on reducing the heat and noise.

Figs. 2 ALN offices & residential housing by ALN architects, building process and finalized (*Photo* Author, Gabriela Obert)

Ingredients of this material are very unique and not public to a lot of companies. The price for this material was around 800 euros for m3 back in 2014. Since this type of project was going to be the first one in Landshut and Bayern, the company was aware of the unexpected losses. Thus, the company decided to hire a team of 3 architects who were experts on insulating the concrete, including the researcher (Fig. 2).

To date, the researcher and other's company was working in an old way by using CAD 2D drawing, thus preparing plans and sections separately. 3D modeling was something very futuristic and not for daily use in their company. When the researcher mention daily uses, he meant that the company only used 3D modeling for special occasions such as competitions and for special clients.

When the researcher first saw and analyzed the initial project, he became very much concerned. The project had elementary problems and the researcher and others, including the CEO and managers were very aware of it. To the researcher's consent, using insulated concrete as the base material was one of the major problems since insulated concrete had an extremely high initial cost and raised the project's cost tremendously even though the structure of insulated concrete would have a future impact on architectural qualities and beauty standards.

The pressure on the office toward the researcher increased daily, while the CEO and his colleagues expected the very best future representative design from him. By knowing and considering its benefits, the researcher decided on his own to develop the project on a BIM program. Back in that time, he had a team of three supporting architects and none of them was familiar to BIM.

This was the very first time that anyone from the company colleagues and the researcher and other's company office management has ever heard about BIM data modeling. At the very beginning when the researcher started this project, many of the company's employees offered minimal support to him, except for the one CEO–Markus Neuber who recruited him.

There were continued big clashes in the office about the BIM system since no one wanted to know about its benefits, and they stuck to their stubborn arguments

as the way how the researcher and other's work was perfect; they did not need to be changed to something new; the program was not tried before, and it would take them too much time to build the 3D model rather than just building a very 'simple' 2D. Yet, with the researcher's persistence, they started the project on BIM within his personal computer.

After three weeks of work and precise calculations within the BIM system, the researcher and others envisioned that the total cost of insulated concrete was going to cost four times higher than normal concrete. Thus, with their BIM project, they already saved around 2.5 million Euro, reducing projects' initial cost up to four times. This was great news for the CEO and the company in general. Thus, the company allowed the researcher to use his computer as an official BIM program provider that other employees in the office could also use. This was a big step toward using 3D modeling for presenting the researcher and other's plans.

During the next four months, the researcher intensively worked on 2D and 3D models of their new office in more than 89 versions of design including all plans, section facades, details, materials, and 3D models showing the rendered views, culminating in presenting the results to three CEOs of the office. This resulted to be the first time after three years of discussions when all CEO members were united regarding the design plans for their future building. After four months of intensive work and with great confidence, the researcher convinced all CEO members of his design.

By using BIM, the researcher and others shortened their projecting time from 2 years in 4 months. The building resulted to be extremely cheaper than what they expected, and thus, they saved costs for architects, engineers, experts and also saved building costs and avoided any changes requested from government authorities. When talking about government authorities, it is worth mentioning that this was the first time in 40 years that the German government authorities involved themselves in a BIM project.

The project was accepted by governmental authorities on its first proposal, due to the innovative project designing system, practical managing, and organization. To conclude, BIM software saved the researcher and others a lot of time and energy so that they could also work and manage different projects at the same time. The researcher was the luckiest to serve as the project leader for one of the most important projects for the identity of the company.

4 Interview with Markus Neuber–CEO and Project Leader in ALN

Markus Neuber, born in 1975 in Landshut, studied civil engineering at the University of Applied Sciences in Munich, with a focus on project management and construction operations. In 2003, he founded his first office with Barbara Neuber. In 2008, they bundled their knowledge, expertise, and architecture, merging with their present

partner Peter Leinhäupl, into the 2nd generation as ALN Architekturbüro Leinhäupl + Neuber GmbH.

In addition to the architectural quality and functionality of their buildings, sustainability is a fundamental issue for Markus Neuber. Markus understands full well that construction is only a small aspect in the entire life of a building, and that determines its entire life cycle—regardless of whether it is a detached house, school, or clinic. As an architect with a project management background, Markus Neuber thinks in an interdisciplinary method. Both in his own office with architects, civil engineers, interior, and landscape architects, as well as in cooperation with architectural offices such as Behnisch Architekten or Bakpak, the focus is on the exchange—and of course on the success of the project.

4.1 Advantages and Disadvantages of the Project Working Within BIM 3D?

Working on the project in 3D

Advantages:

(1) 3D model to check the volume and composition of the building.
(2) Evaluation for areas and derived possible cost–potential savings in manpower and time; less prone to errors.

Disadvantages:

(1) Employees need special software knowledge.
(2) The working effort is much higher at the beginning of the project.

What Would be the Difference if This Project was Processed in 2D Software? Advantages and Disadvantages?

Working on the project as a 2D model.

Advantages: The employees do not need any special software knowledge. A conventional computer infrastructure is sufficient. No increased effort in early project phases. *Disadvantages*: No processing of the planning task in a digital model. A digital spatial check of the composition is not possible at all times. A quick or short-term evaluation of the planned project is not possible without considerable manpower expenditure.

4.2 Design Experience of the N188b Project?

The researcher and others were able to organize and drive the design process much faster and more efficiently. Due to the different geometry and topography alone, a

3D model of the building's cubature together with the terrain was essential. The researcher and others could integrate the models created in ArchiCAD directly with Rhino and Grasshopper. In this way, they had better control over the building volume in all phases, especially in view of the building's slightly different geometry, which doesn't utilize ordinary shape solutions where each wall is at right angles. Working in BIM has allowed them to respond to the building's immediate environment and topography, while still keeping track of all area and volume data. They were also able to design more building variations in a shorter time frame and evaluate them for their functional and material suitability, without any great additional manpower.

Data exchange with the specialist participants who themselves are already familiar with the BIM procedure was also much simpler and more effective. Many intermediate planning steps could be skipped, and interface management and control were made easier.

What will the Design Experience be Like if the Project was Processed in 2D Software?

Based on the researcher and other's years of experience, they knew that the classic design process as they have practiced it for decades would have required more staff and consumed more time for the training. Within the team of architects, the tasks would have been distributed as follows: 2D drawings in ground plan, sections, and views, different models in different scales would have to be built, cost estimates would have been provided manually in Excel. Bringing all this information together, of course, carries the risk of data being lost, misunderstood, or misinterpreted.

In addition, the data exchange with specialist planners by dxf and dwg files takes place on the lowest common denominator. The parallel work results in several work states, which have to be merged. This is not only more time-consuming but naturally leads to a higher risk of mistakes.

4.3 Quality Experience of the Project Within 3D BIM Software?

In principle, the quality of planning can be significantly improved by working on a project using the BIM method. This is largely due to the fact that there is only one data source. The information can be filtered, read, and distributed in a wide variety of media. It is possible to produce classic paper plans or to read out information in tables, and from there process them and return them to the model. Using small additional software products, other project participants can also take a look at the model and extract information from it. The Industry Foundation Classes (IFC) interface makes it easy to exchange information between the various disciplines. The BIM Collaboration Format (BCF) can be used to develop, test, and release processes. These possibilities do not exist in traditional (2D) project processing or can only be created using external data sources that are not connected to their drawings. This results in errors and loss of information.

The use of all these possibilities requires well-trained employees and planning participants. Here, one must admit, however, that there is still a large and prevailing backlog of demand. In addition to planning, the implementation of projects also benefits from processing as a BIM model. However, there is an even greater backlog demand from the executing companies. The only companies which have the possibility to pre-produce their performance will have the technological possibilities to use the advantages. The classical crafts enterprises are still far away from this.

The increased quality of planning and execution can, of course, also be passed on to the building owner or developer. The model can be used to visualize the various operating states of the building. Augmented reality allows the facility manager to display information on specific components within the building on a computer tablet. Repair processes can thus be automated.

What Would Have been the Expectations if this Project was Processed with 2D Software?

Plans are produced in the classic CAD solution. Ultimately, this is not much different as it was before the age of CAD planning. The user constructs the building, line by line. Whether this is done on paper or with a computer is basically irrelevant. In addition to the pure construction drawing, further information can be added via text or markings. These can also be added bit by bit. If too much information is entered into the plan, the clarity and legibility of the plan will suffer. The information density of a classical plan is therefore very limited. In order to be able to pass on the information to those involved, it is necessary to rely on further documents. In addition to the plan, countless lists, tables, and documents are transferred. The danger is that these different data sources do not all have the same status or source. A classic risk is, for example, the door list. This must be continuously updated during the planning phase. If, for example, the opening direction of a door is changed during planning, this information must also be included in the door list. If this is not updated, the door is simply delivered incorrectly, or in the worst-case scenario, will be installed incorrectly.

With the present project, there surely would have also been this kind of error in 2D planning. Furthermore, it would certainly have been more difficult to construct the complex geometry of the building in 2D without errors.

4.4 The Team Involved, How Many Team Members Were Involved in the N188b Project?

The design and planning team on the side of the architect was between 1 and a maximum of 5 employees. The structural design consisted of an engineer and a draftsman. The team of climate engineers consisted of 2 engineers. The planning for MEP was done directly by the contractor based on the concept of the air-conditioning engineers. The planning for electricity was done directly by the contractor. Formwork planning and detailed planning of the fair-faced concrete walls were carried out in

cooperation with architects, structural engineering, and technical management of the contractor and formwork suppliers. In addition, there were engineers and experts for the excavation securing, foundation engineering, room acoustics, fire protection, and water regulation specialists.

Do You Think This Number Would Have Been Much Higher if This Project was Processed With 2D Software?
The initial effort required for BIM-based planning is higher than for classic 2D planning. Setting up and defining planning criteria, as well as the structure of the working environment, cross-location, and cross-disciplinary team structure, etc., would result in a time-consuming project and data preparation before one can really get started. In the course of the planning process, the planning team is certainly clearer, but depending on the complexity of the project, an additional worker (team member) may be required: the BIM Manager.

4.5 Design, Are You Happy with the Design? Do You Think that if the Project Was Designed with 2D Software It Would Have Had the Same Features as the BIM 3D Design?

The researcher and others are very convinced of the design, i.e., of their draft. The complex building geometry was constantly checked using the 3D model. In the BIM model, intersections of surfaces and levels could be identified and processed earlier in the workflow. However, the concept of design remains the same, whether designed with a pencil, the 2D CAD program or BIM. The tools may be different, but the design process remains the same which utilizes the intellectual work of the architectural team. However, with the help of BIM, it can provide planning benefits in terms of greater transparency and quality.

4.6 Do You Think that the Same Project Design Would Have Been Managed with 2D Software Within the Same Period of Time?

Project work using the classic 2D method could only have taken place in the same period of time with a corresponding increase in human resources. In addition, there would have been more coordination sessions between the project participants, and later decisions on the part of the client, which might have prolonged project planning duration.

4.7 Ability to Change the Design, Did You Have Problems in Finding the Final Design?

The design of the building was quite a challenge. The location of the building site at the border between the historic city and the wild green belt of the castle hill was a special urban development challenge that had to be solved. The topography of the castle hill's steep slope did the rest. All these conditions had to be brought into balance. These points were solved well with the help of three-dimensional planning in the model. With the support of Transsolar's climate engineers, the researcher and others were also able to further optimize the building in terms of daylight self-sufficiency and energy performance.

However, countless variants were studied up to the final shape. These were modeled both on the computer and on paper. The structural design also optimized the statistics with the help of the model. The building absorbs the entire slope thrust of the upcoming castle hill and transfers the loads through the building and into the foundation. The result was a very simple but effective static system which gave the researcher and others the greatest possible freedom in designing the rooms.

Once the design was finalized, it was very easy to integrate more and more information into the model. Here, you can feel the full advantages of the BIM model.

Would this Project have had the Same Amount of Design Possibilities if it was Processed with 2D Software?
With enough time and additional human resources, surely. However, the project would have required additional funding for planning. Additionally, the advantages of a BIM model could not be utilized in this state. Plan changes would not have been immediately checked for cost effects in 2D software which is something that can be done with BIM.

4.8 Working with other Engineering/Architectural Companies. How was the relation and communication with other project participants as, e.g., the construction company (Brandl Bau) and the client during the Design Phase?

The cooperation with the various parties involved was partly based on the exchange of the BIM model in IFC and partly on the classic dwg/dxf model. The exchange with the facade company (Neumayr) was made via IFC. The factory planning was then incorporated directly into the researcher and other's model by the company. The coordination was done in appointments or by telephone. The company then gave the researcher and others their information on windows and façades for further processing of the planning. The researcher and others then transferred this information into their model.

The structural shell contractor Brandl, for example, created the formwork planning for their services on the basis of the researcher and other's plans, the model. With this planning, Brandl generated the formwork pattern (size and shape of the formwork, anchor pattern, etc.). After approval by the researcher and others, the company optimized the switching cycles and the amount of formwork available on the basis of the planning. This ensured that only the required amount of formwork material was kept on site. The MEP planning department developed planning based on the researcher and other's model. The approval process for the position of the visibly mounted cables was thus significantly sped up.

Would this Phase Been Easier to Manage if this Project was Worked with 2D Software?

(1) Most likely not. For several reasons:
(2) Missing consistent data without a single source model
(3) No consistent work processes, instead of more checking procedures and more data export and import transactions combined with a significantly increased risk of mistakes, longer checking and approval processes, lower efficiency.
(4) All architects working in different files, which means several parallel processing stages.
(5) Planning partners also work on various files and related processing statuses. This means more training and coordination activities, which increases the risk of mistakes when exchanging information.
(6) The relevant work statuses must be laboriously merged into a final status. This naturally entails a high risk of errors. The avoidance of mistakes requires a high degree of control. This makes the planning process inefficient.
(7) The evaluation of the area and volume changes and thus also costs must be manually revised and recorded in various media (CAD, Excel tables, project management programs, etc.), which usually means higher manpower and time expenditure.

Access to a single data source, a shared BIM model stored on Graphisoft's BIM cloud may already significantly reduces the rate of errors and thus increases efficiency in the planning process.

4.9 Ability to Work Within Building Construction Chain. Do You Think You Managed the Shifting from the Planning Side to the Building Construction Well?

In this project, the transition from planning to execution was rather fluid. This was due to the fact that the researcher and others involved the companies at an early stage in the planning process. They made the model available to the companies. Then, the companies had the opportunity to create their planning directly on the

basis of the BIM model. This had the advantage that there were no transmission errors in the distribution of the information. The planning could be completed faster. The companies did not have to make their own plans on the basis of "normal" CAD files exported by the architects. The companies' plans could then be imported back into the researcher and other's model. A loss of information was thus nearly impossible. The verification processes by the architects could also be reduced. By checking the incoming model of the companies in Solibri, the researcher and others can detect possible errors before actually importing the data into their model and return them to the company for correction. The result is that they only insert the "correct" information into their model and continue working on it.

What Would be your Vision if the Project was Processed with 2D Software for all Design and Construction Phases?

The design phase would certainly have been much more complex. The complex geometry would have had to be constrained. This would then have had to be checked using an additional 3D model in order to avoid unplanned corners.

The approval phase could have been implemented in the same way without any major problems. The detailed planning would certainly have been more complex to implement. In addition to adjusting the scales from M 1:100 to M 1:50/20/10/5/1, the changes would have been much more complex to implement. The planning of the formwork and the exposed concrete walls would have had to be based on 2D plans (ground plans and wall developments). The risk of errors would have been significantly higher. The accounting of the services according to plan would also have had to be carried out classically with calculations and Excel lists. In summary, the processing of data would have been much more time-consuming and prone to error.

4.9.1 Building Costs, What Are the Building Costs of the N188b House?

This was a private project, and the client has asked that the researcher, and others would withhold further details. In general, however, the researcher and others can say that the costs for the usable area are very high. The reasons for this are not so much the planning but the complex realization of the project. Due to the close integration of the development into the direct surroundings and the very narrow access roads, efficient handling of the construction site was difficult.

Do You Think That if the Project Was Processed With 2D Software Would the Project Have the Same Price and How Much Will This Affect All the Building Chains?

The costs of the building have certainly not been significantly reduced by processing as a BIM model. Basically, the costs in planning with BIM are easier to determine and track faster and more accurately. This helps to make reliable cost statements at an early stage of the project.

5 Conclusion

As a conclusion regarding to the design and information management, is that BIM as a new approach in design and construction provides the system of a great collaboration between different disciplines to create and complete, seeking the real-time virtual model of the building, shorten gaps in between different teams, and also creating a unique structure in all designing and building process. The convenience of a 3D model is the cost and time-efficient process, as well as a significant reduction in errors, which can be discovered much earlier. By adopting BIM as a Tool, it gives an opportunity to re-tool the company operations.

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