Data driven design

Changes in Architecture through extensive use of BIM in the early design stages?

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These days the world of Architecture, Engineering and Construction (AEC) is in turmoil as BIM (Building Information Modeling) slowly but surely kicks in. After a brief description of the virtues and limitations of BIM we explore if and how the use of BIM in the early design stages can change and possibly improve the quality of the built environment. Based on experience and knowledge, we provide a clear reflection on the impact of BIM on architecture in the early design stages.

KEYWORDS: BIM, BEM, data driven design, eco-design, early design stages

1 Building Information Modeling

1.1 Features

BIM generically can be described as the green engine for contemporary sustainable design practices. But what exactly does BIM mean or stand for? BIM is not a particular kind of software it is a process. BIM is about communication and management of digital building information in an interdisciplinary team.

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Through BIM the information management before, during and after the building process is being optimised and the productivity consequently increased.

In the current architectural workflow many parties from different disciplines are involved in the realisation of any large construction project. However, as the general context of the building process is continuously in motion, roles and responsibilities of the stakeholders change regularly. Due to this nonstop context change, the amount of data and the dynamics of the construction process make the probability of errors fairly large, which results in extra cost (cf. Flyvberg e.a., 2003).

Through BIM, all relevant building information is stored and managed in *one* digital model. All parties involved work with the same information. The point of departure is to have data clearly structured, continuously available and always up to date. Where this way of working is new and revolutionary in Architecture, the automotive and aerospace industries have been successfully applying similar process methodology and information storage for many years now.

In order to change the current linear building methodology, ranging from initial idea and study phase over design and construction into management and demolition, into a circular oriented model with dynamic data in the centre, there are some specific requirements.
All participants, without exception, in the interdisciplinary project team have to use BIM as a tool implementing a universal format, the open standard IFC2x3[1], to exchange project data. This generic common language is vital for communication during the lifecycle of a project.
Furthermore, a model manager or BIM manager is required. Until now this new role in the building process has not been strictly defined and is often taken up from within the AEC environment.

As a result of BIM, any conflict or 'clash' between architectural, constructional engineering and MEP (Mechanical, Electrical and Plumbing) models can be acknowledged in an early stage and thus prevented. Fail-

[1] FC-SPF is a text format defined by ISO 10303-21 ("STEP-File"), where each line typically consists of a single object record, and having file extension ".ifc". This is the most widely used IFC format, having the advantage of compact size yet readable text. IFC2x3 (2006) is the version currently in use.

ure costs are expected to be greatly reduced through structured methodology of workflow and data.

Whilst data in BIM can be accessed throughout the entire lifecycle of a building, it also can play a role during the usage of this building. Facility management or, a little less extensive, querying the database for service dates of fire extinguishers both lean on the data model.

Even during the demolition phase BIM can play an important role as the data model provides answers as to where materials have been used thus facilitating easy destruction.

Next to offering new technical features, BIM is or will be a requirement in the tender process where it already is an integral part of the government strategy for the building sector in countries as the UK and The Netherlands. The input of BIM is broadly based on sustainability, energy-efficiency and meeting climate change targets. The EU Sustainable Construction Strategy has the potential to acknowledge that BIM will enable European architectural, engineering and construction companies to maintain their presence in global markets while the European Commission is also reviewing BIM as part of its on-going revision of the EU Procurement Directive.

The above, concise description of features of BIM are critically discussed in the following section.

1.2 Conditions and limitations using BIM

Almost in contrast to the extensive use and on going optimisation of information management in everyday life, BIM is not just a temporary phenomenon or gadget. Within BIM all kind of information can be unambiguously connected to any part of data model with a low threshold for users. For instance, a visual interface (such as a tablet) can be used for maintenance or repair with support staff being able to exactly determine which element should be replaced as well as specific technical information such as a type of lamp or the height of a ceiling. In this way, waste of time and efforts can be prevented.

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Not everything is always in favour of BIM. As there is a huge amount of data involved in the building process, it is rather important to safeguard the signal versus noise ratio. Not only should users be protected from an abundance of data, also the interpretation of the available data should be unambiguous. This is guaranteed via IFC certification of the software being used.

Because of the large amount of data, it is important that people with the right skills and knowledge will work with or manage the BIM model. With a BIM manager, BIM coordinator and BIM modeller a number of new job descriptions are created within architecture, engineering and construction.
The BIM manager operates on a strategic level. No matter how large the project, you only need one person responsible for this strategic function. However, a BIM manager is not simply a rebranded CAD manager. Business and project size determine the structure of the BIM team; a BIM manager could perform all functions on smaller projects.
On the other hand there is the need for a BIM coordinator, who works on management level and who is project- and BIM-specific. The coordinator helps to set up the project, audit the model and co-ordinate with all collaborators. The coordinator can manage several small projects simultaneously.
Finally, BIM modelers are required with primary responsibilities for modeling and drawing production. BIM experience is not essential to produce the model but technology skills as well as 3D awareness and thorough constructional knowledge certainly are.
Each project has only one BIM manager, while there could be more BIM coordinators or BIM modelers.

As own experience proves, management of building information in a data model is far more up to date, accurate and efficient than having material on different plans with no *actual* relation.

Last but not least, keep in mind that using software able to export BIM data not necessarily is the same as being involved in the BIM process. In the near future architectural practitioners will be split between those who manage their data and those who let their data manage them.

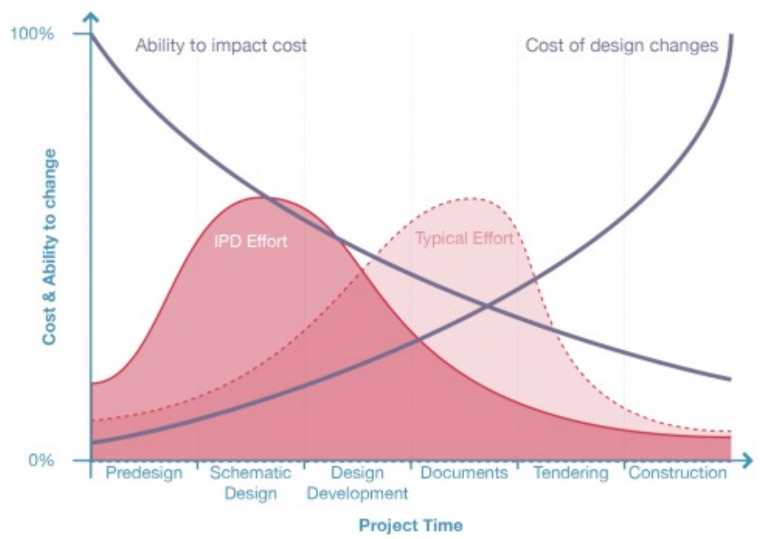
Where BIM is not necessarily hampered by specific conditions or limitations, there are good reasons to start using BIM as early as possible during the design process.

2 Early design stages

BIM is not an endpoint; it can be the start of much more than the traditional architectural output. Because of the use of BIM, the early design stages are the ideal moment to introduce sustainability concepts, such as the economy of a Building Energy Model (BEM), control heat- and airflows with Computational Fluid Dynamics (CFD), initiate clash control between architecture, engineering and construction models, start consistency checks with building programme and external regulations and better communications and understanding between the actors through 3D visualisation.

During this early phase, developing design alternatives which impact the project cost most still is possible as the cost for rigorous changes in this moment of project time is least.

Figure 1. MacLeamy's curve (2001)



'Eco-design studies' are generated from BIM, preferably in he early design stages, and not only take into consideration economic, technical or human criteria but also the environment. Eco-design, sometimes also called data driven design, focuses on both energy- and water-efficiency with a passion for passive design strategies and renewable energy. In this way sustainability in architecture becomes an intrinsic value and an essential part of the design process.

The following paragraphs examine different applications using BIM for eco-design analysis.

2.1 Building Energy Model (BEM)

Based on BIM data, BEM establishes a significant role for lifecycle analysis and sustainability assessment frameworks in architectural design. This is of major importance as buildings are among the largest consumers of energy and raw materials, construction stakeholders should be aware of both environmental and construction costs.

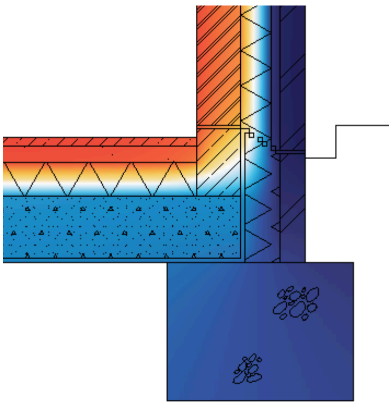
BEM is an ANSI/ASHRAE Standard 140-2007 certified energy tool that can be used to monitor and control architectural design parameters that influence the building energy performance. These parameters can be divided into three groups. First of all there are *fixed* parameters (climate of location, occupancy behaviour, process energy, required air change rate and allowed indoor climate variation range). Additional there are *constrained* parameters, like wind or surroundings (green, buildings and surfaces). Finally there are parameters that are *alterable* by an architect, for example building orientation, building shape, glazing ratio, MEP…

An energy balance calculation computes the energy demand, i.e. the amount of energy necessary to operate (heat, cool, ventilate, illuminate) a building. If mechanical, electricity or plumbing (MEP) systems are assigned to fulfil energy demands the specific amounts of fuel they use can be calculated. However, not all 'fuels' can be considered to be on the same scale. Whereas some require tremendous initial energy input to be produced (e.g. electricity from coal), others come for free (e.g. electricity with photovoltaic panels from solar radiation). The primary energy data represents this initial energy input. If the building's energy demands are minimized in the early design phase of a project, it will also be more energy efficient in the final design phase when MEP systems are calculated and their parameters included in the definitive energy analysis.

In order to accurately determine energy demand, the architectural design must be analysed in the greatest detail possible. Input regarding building systems when starting from BIM can be reduced to the necessary minimum, enabling architects to design maximally energy-efficient buildings without having to rely on input from engineers or specialist consultants.

A model based solar irradiation study can be performed where solar gain through each individual transparent element of the building envelope may be precisely determined. Not only taking into account the amount of glazed area exposed to direct sunlight and direct solar radiation on glazed surfaces but with software intelligence determining and taking into account the degree of leaf on green (shading) throughout the year.

Figure 2. Thermal bridge simulation



Furthermore with thermal bridge simulation, the performance of constructional details is being evaluated and the resulting performance values are being used to calculate their effect on a building's overall energy balance. Graphic results of the thermal bridge simulation come as virtual thermal-vision and energy flow diagrams and can be used to analyse the temperature curve in and discover the amount of heat transport through an architectural detail.

Reports can be generated with simulation data such as annual peak heating and cooling loads for thermostat controlled cases and annual maximum and minimum zone air temperatures relevant for environments with free float internal temperature (atriums, conservatories, unconditioned staircase blocks, …), with date and time of occurrence. Results from a BEM can also be exported to external energy calculation tools to comply with national required output standards.

2.2 Computational Fluid Dynamics

CFD is a mathematical modeling procedure for solving basic physical equations of fluid mechanics. Mathematical equation of mass, momentum, heat transfer and species concentration can be solved for air in a three-dimensional space and used to visualise both internal and external heat- and airflows.
In this way CFD is being used in architecture, engineering and construction for climate control, wind nuisance and wind load analysis. Increasingly it also is a method to investigate the discharge of smoke and heat in fire research. Next to controllability of a fire CFD can also be used to determine safe escape routes and ultimately also the possible collapse of building structures.

Using CFD in architecture by using data from BIM delivers extra value for sustainability especially in the early design stages where necessary changes still can be made without huge cost implications.

2.3 Model checking

Where BEM and CFD start from and generate something new out of BIM data, model checking is all about objects and numbers themself.

Starting from BIM data it is possible to check for conflicts between various models (e.g. architecture, structural and MEP) as well as to verify the consistency of the design proposal against an architectural program or brief using a so-called model checker.

However, in spite of model checking, clash detection and examination of building rules and regulations, it remains even better to avoid clashes through volume coordination in an early stadium.

2.4 Visualisation

Better interaction and understanding between different stakeholders in the building process can be achieved and improved through generating 3D visualisations of the project. The scope of these visualisations ranges from still images and movies to a virtual building environment one can explore, possibly completed with Augmented Reality (AR).

Augmented Reality is a state-of-the-art technology for superimposing information onto real worldview. In this way visualisation reaches parts where no one boldly has gone before, for instance, overlaying building information onto an existing structure. In this way measuring and interpreting key differences between the real and augmented views of a facility can quantify structural damage.

2.5 Schedules and lists

As BIM stores all the information of a building it can be leveraged for stimulating applications including the generation of quantity take-offs, 4D scheduling (i.e. 3D + time) and building simulations and 5D estimating (i.e. 4D + costs). In this way BIM data is an unlimited source for generation of schedules and lists.

3 Unlock the secret

Even with new job descriptions in place, one should not underestimate starting with BIM. Where architectural practices many years ago swapped the traditional drawing board for CAD, changing CAD into BIM is a much more far-reaching evolution. Traditional plans, sections or elevations are just one way of appearance of data generated from a BIM. Instead of one particular building-section with BIM you now just can generate as many as you (or multiple users) like or, at the switch of a button, produce a three-dimensional presentation, without having the fuzz of almost in a tailor-made way generating slides one-by-one. Apart from plans, data also can appear in many other ways, for instance as a list of surfaces and volumes or a bill of materials.

Where it might be clear that BIM can be the catalyst for contemporary sustainable design practices, a strong locomotive is needed to get the process firmly under way. To our estimation different actors, through 'push'- and 'pull' –strategies, can facilitate the transformation. For instance, the Rijksgebouwendienst in The Netherlands makes a BIM model obligatory for any contractor they work with. In the UK BIM stage 2[2]

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[2] A managed 3D environment held in separate discipline BIM tools with data attached. This level of BIM may utilise 4D construction sequencing and/or 5D cost information.

should be applied and in France and Germany implementation levels of BIM in the construction sector are even higher than in the UK. Still, many countries do not really offer any specific prospects or policy yet.

Where BIM waits for a true stimulant, is it the building owner who ultimately will step forward, getting a green conscience and realising the financial assets of Eco-design? Or will contractors in general and the MEP sector in particular step in as they benefit most from the use of BIM with dimension and position of (either construction or installation-) elements being a major point of attention in the early design stages.

An important trigger for a more widespread implementation of BIM is the prospect of substantial cost reduction. Factors cited as having a high to very high impact on improving return on investment (RoI) from the use of BIM are a better multi-party communications and understanding from 3D visualisation, improved project and process outcomes and lower project cost. The extensive use of BIM, particularly in the early design phases, can help to achieve these goals.

"The secret to getting ahead is getting started. The secret to getting started is breaking your complex overwhelming tasks into small manageable tasks, and then starting on the first one." That's the advice Mark Twain offered over a century ago. This still is particularly true in terms of BIM implementation, especially in the early design stages. It's not a rage, it's real and it's now. You cannot afford to wait until later!

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The UK Government's BIM Strategy Paper calls for the industry to achieve Level 2 BIM by 2016.

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