Modeling building physics: a tool for integrated design

Dramatic changes in the environmental balance on planetary scale call for a new energetic consciousness. Various studies have indicated the importance of the building sector in general and architecture in specific in climate action. Now stronger than ever, high (legal) performance standards, for both comfort and energy demand, stimulate fully integrated architectural and engineering design.
Computational modeling can be one of the strategic means to further promote this integrating reflex in architectural practice and education. Simple static 2D models are easy to use and even to build in a spreadsheet. Nevertheless, they provide quick and crucial information on feasibility of design options and architectural detailing, bringing more cohesion to the architectural concept.
On a different level, advanced dynamic modeling can have an even greater impact on the design process since it will provide detailed information on the viability of the whole integrated concept of the building. By introducing modeling early in architectural courses, students have the opportunity to develop skills that enable them to create and interpret these powerful tools.
To achieve fully integrated buildings, attention must also be paid to the execution phase of the building project. A 4 of 5 dimensional approach of modeling, which incorporates planning and technical data, provides robustness to the concept. These models (BIM) are still highly experimental. Not only will applying them in architectural courses facilitate their introduction in common practice, it is a powerful review mechanism to further improve them.
By reviewing a 'Low Energy Building'-seminar and a design project in Masters classes, the advantages and pitfalls of these approaches will be discussed.

The building process: a historical perspective

Without any pretention for accuracy, a short overview of the evolution that has marked the building process throughout history will put the present day situation in a more elaborate perspective.
Since the very beginning of building, it has been a group process. Building involves substantial charges and complicated manipulations that necessitate the involvement of more than one person.
Where it can be assumed that at first the owner himself and a group of helpers constructed the building to their on ideas and possibilities, soon specialization brings about the introduction of the professional builder. The exponent of this all-in-one builder is the medieval free mason. From this point on, further specialization due to increased need for technical knowledge and development of esthetical theory introduces figures like the engineer, the (specialized) contractor and the architect to the construction field. Although the distinction between the 'designer', the 'calculator' and the professional 'executor' can't be made as sharp as this formulation would suggest, the principal idea of progressive specialization is essential.
The next step involves the appearance of the technical engineer, the acoustical engineer, the building physics engineer, the state agent, the insurer, security advisor, the EPB reporter, urban planning authorities…
The field of people engaged in the building process is ever expanding, as is the number of specialized branches within the process. Each of these actors has his own agenda and expertise. This often introduces not negligible coordination difficulties into the project. Technically, the project benefits from the dense competences that are addressed, but the diversification of actors in the process

launches new challenges to the means of communication. On top of that, the growing complexity of the building process renders most projects impossible to handle by the traditional one-man architect. Group practices and partnerships, where every member has his own specialty now represent most of the architectural offices.

Next to the ongoing concentration of the activities around these specialisms, the representations used in communicating the project have undergone considerable technical improvements since the introduction of graphical computer programs and CAD-standards, but the basic form of representation did not change since the medieval realm. The common form of document that is passed on between the different partners now controlling the building process, is still the 2D schematic plan. As buildings become more and more complex due to scientific progress in the field, the shortcomings of this technique increasingly limit the efficiency of the output. Since economical imperatives contrarily require increasingly higher effectiveness, alternatives receive elaborate attention in contemporary literature.

Although their market share is still limited, new 3 dimensional component based virtual models (BIM)(1) steadily gain importance because of the triple advantage they have over the 2 dimensional drawing. Firstly their open platform architecture makes it possible for every user in the project to access and append the same model, which decreases double work and copying errors significantly. It is evident that the mentioned coordination issues are largely tackled by this. Secondly they offer a much more ‘tactile’ model for the owner to judge the different alternatives proposed by the partners. Thirdly they provide a robust platform for the exchange of electronic information. Due to the ongoing specialization, each task of the different actors has a high level of professionalism and involves progressively more computation. Computer models in fact become the very basis of most of these activities. Resolving compatibility issues between the different models is one of the main reasons for and merits of BIM-development.

Simultaneously with BIM, the classic triangle of Architect, Contractor and Owner is broken and replaced by the ‘Building Team’. In the classic configuration, the architect designs the project in relative isolation and the contractor executes the design. This exaggerated but nevertheless meaningful witticism shows the explicit responsibilities of the different parties in the contract. This formalism is legitimize by its ‘objectivity’. Since the architect is responsible for the entire design, he will be critical in assessing the quality of the work done by the contractor and since the design is not ‘owned’ by the contractor, several contractors can be consulted, resulting in the best possible price.

Although these merits are often true, the altered context of the building process reduces their profitability considerably. Not only does it require tremendous amounts of energy to produce a complete and objective file for every project, the useful knowledge of contractor is completely ignored. Because of this waste of knowledge, incompatibilities between certain proposed components are often overlooked, causing pressing problems during execution.

Within the ‘building team’-configuration, the contractor and all other partners in the building process are chosen from the very beginning and all of them contribute to the design. This way, the incompatibilities should be overcome. The early involvement of the contractor also makes it possible to reduce considerably the total length of the building process, from initial intent to build to completion. Of course, this also reduces the objectivity of the design. Practical experience teaches that the balance between pro’s and contra’s of both arrangements is not univocal and should be considered for every project individually. A decisive parameter in this balance is certainly the complexity of the project. The more difficult and the bigger the project, the more the advantages of the ‘building team’-approach will dominate the disadvantages.

Generative energetic assessment

Within the building process, energetic and building physics modeling (and by extension all technical modeling) can be implemented in two ways: either it can be a limiting assessment that renders existing proposals ‘impossible’ or it can be a generative instrument. Although it is clear that the second implementation is preferable, technical ‘boundary conditions’ are often perceived as limitative. This aversion towards technical issues is plainly visible in the place the engineer occupies in the classic design process. All too often a finished design arrives at his table for him to ‘solve’. The implementation of building technology in this design is then repeatedly impossible without spoiling the architectural quality.
When on the other hand these ‘boundary conditions’ would be approached as possible narratives for the concept, they could possibly add value to the whole in stead. Sufficiently accurate and user-friendly models that offer the possibility to immediately evaluate the performance of a design alternative or a decision. This performance can as well be energetic (EPB)(3) as ecological (LCA)(4) or economic (planning, budget) etc. Here to the recent emergence of BIM and the ‘building team’-approach offer additional possibilities. With the use of BIM, the designer receives important feedback on the quality of his concept on various benchmarks. The building team makes sure that the intellectual resources to interpret the results of the benchmarking and put forward realistic goals are present from the very beginning.
The designer can no longer hide in ‘perfect isolation’ but has to share some of his decision making authority with the other partners. Once again, the ‘objectivity’ of the design will be less, but when all actors in the process are sufficiently talented, the final concept will be significantly richer because it encompasses different fields, forming a well integrated design.

Pedagogical Background

Collaborative learning is, although already vastly discussed in literature, still the subject of a lot of research in pedagogical science. New models and findings are published frequently. Most of the research agrees that collaborative learning is a high performing setup for a learning environment. The learning results achieved by every group-member are highly dependent on the specific construction of the collaborative environment and the design of the assignment. (5)
Next to more evident criteria like a clearly defined task, a description of expected output etc. the assignment of specific roles to each of the students individually proves to be determinant. To achieve the maximal efficiency, students need to be both dependent on the total result of the group and their own individual work for the final evaluation of the exercise. This makes sure that more perspectives of the assignment are included in the discussion and that each student has to contribute substantially since he of she can not claim the work of someone in an other field.
The roles the students take should be chosen carefully. Most of them will naturally be within the possible positions the student will have to fill once they enter the job market. On the other hand, some ‘opponent’ roles (like the contractor or the accountant in the building process) can be very interesting since this perspective is

usually not included in the process and causes the concept proposal to be imbalanced.
From the teachers side, careful consideration is needed when distributing the roles and allocating students to the different groups. Special attention needs to go to the ‘career’ of the over successive assignments. Although specialization is normal – students regularly tend to choose the tasks they like or know best – the staff needs to make sure that a sufficiently broad spectrum is covered during the program. This means that sometimes students will need to be forced to take a certain role against their role. The importance of the individual final attainment levels for every role can hardly be overestimate in this matter. This prevents students from altering the description of their role to such extend that they manage to ‘escape’ the curriculum items they dislike.
To manage the information exchange needed for these assignments, broad research on computer assisted collaborative learning (CSCL) environments has been conducted i.e. by Valcke (6) and indicates that the learning output of the assignment is highly determined by the setup for the communication environment, both in face to face meetings and in CSCL. One again, the quality of the preparation of the exercise by the staff is crucial.

Conclusions for education

From all considerations mentioned above, a few general conclusions for the organization of architectural education can be deduced. The field of the building process is in constant motion, with ongoing specialization and ever growing complexity as thriving forces. Computer models increasingly dominate the activities of the different actors. The emergence of multi-person offices as a new practice-standard in the architectural field was already briefly discussed. Moreover, the ever larger group of people involved in the building process was elaborately touched in the first paragraphs.
With this perspective for his future employment, the contemporary student in one of the disciplines of the building sector, should acquire excellent communication skills next excellent competences in the specific part of the spectrum the program addresses. Within these skills both soft skills and technical skills are included. While technical skills like being able to clearly represent the envisioned proposal in comprehensive drawings, models and schemes for the other partners can be learned individually, soft skills like tact, discussion management, reasoning and judging the value of an argumentation are in essence learned in interaction.
In most educational programs, the need to develop these interactive competences is mitigated by forcing the students to work together in (small) while working on a project. Pedagogical research indicates that this form of cooperative learning is a very powerful instructional tool, but also points out the high context dependency of the efficiency of the technique. The danger lies in the difference of the individual learning curve of the cooperators. To assure that all participants learn as much as possible, the specific design of the exercise and the groups is crucial. More specific for the design project, students need to ‘play’ the different partners and oponents (or at least some of them) within the building process instead of all being the designer. The final result should also be judged on two ‘independent’ sets of criteria. This may include different additional jury memebers for each group member that have explicit expertise in one of the roles.
In addition to these formal constraints, and moreover in interaction with them, the contents can focus on the integration of different

perspectives sprouting from the discussed specialities, different branches of the art etc. in one rich concept.

Case 1. Design Studio 'Kaaitheater'

In this case, I will try to demonstrate how integration is attempted in a design course in the Master of science Engineering: Architecture program at Ghent University. The course is a classic design studio for the first year master students. The course described took place last academic year in a pioneering tryout.
Students tackle a renovation in a theatre building in Brussels, and get the choice which kind of perspective they want to embody. The possibilities were 4-fold: the classic designer, the technical engineer, the civil engineer and the façade-expert. The last three categories are combined to one 'technical studio'.
In a first stage, design teams with only the designers are formed. They start the project by developing an initial special concept. In the mean time, the different groups in the technical studio each prepare specific proposals for typical issues encountered in theater design. After a short initial period, the results of all groups (both designers and technicians) are evaluated by a intermediate jury, giving them feedback on their opening work. After this, where possible, design teams are joined by a technical advisor of each category. They now form a broad group of different actors within the spectrum of the building process as described above. To prevent that the technical advisors either isolate themselves from the original group or abandon their technical mission, they are subject to two final juries: they are evaluated partially on the total quality of the concept together with all members of the design team and partially on a presentation of their own specific work.
To help them generate as much background knowledge as possible, the technical studio also remains active as a whole after the reformation of the groups. In these meetings with all technicians, they discuss problems they encounter and try to develop a few general models that can be used by all design teams (including the ones that did not get technical advisors). The different groups within the technical studio form 'consulting groups' that offer advise on their own subject to any design group that has specific questions. For each of these 'consulting group' a few workshops with experts in the field are organized.
In this case students used all kinds of models and software to communicate their ideas to one another and to the staff. No specific demands were made. On the other hand, the staff consistently asked for numerical proof of the propositions made by the design teams. Models here had both a limitative and generative function. By eliminating options that performed badly, the overall quality of the design improved considerably. On top of that, the general models developed in the 'abstract' discussions in the consulting groups provided additional input for the design process. The combination of this double function with the heterogeneous composition of the design teams (designers and 3 kinds of technicians) from a very early stage of the course rendered more rich and integrated design concepts. Although all groups could benefit from the more rich competences that were available in the studio by means of the consulting groups, the expected increase in quality was especially significant for the teams that included technicians.

Case 2. IFC-master's thesis programs and elective courses

In the case discussed above, the stress was laid on the context and the organization in which models are used in the design studio, how

they are a tool for generating content that augmented the integration of different perspectives in the project and result in a richer concept. In this second case, I will focus on master’s thesis programs and an elective course now in execution in the same master’s program.
The goal of these courses and projects is the development of a tool that combines the advantages of BIM with the flexibility needed for the design process. Based on the international IFC standard, an international interoperability standard, this tool should both possess intuitive (special) modeling capabilities and accurate, powerful evaluation engines for structural integrity, energetic performance, planning, economic feasibility etc. etc.
This very broad research is divided in several subtasks. The research staff is engaged in the development of the main engine of the whole tool: the conversion of richly labeled geometrical data (ifc) (2) to workable definitions of space, volume… From this central engine, the work both upstream an downstream is taken up by students.
For their master’s thesis, 3 students try to link the engine to planning, accounting and visualization software respectively. They focus on the links between these software packages and propose a general strategy for linking the engine to any kind of application. The link should make sure that users of the tool get immediate information about their design and the effect of changes they make.
An other group of students works on the link downstream between modeler and engine in a special elective seminar. They try to generate useful data with very simplistic modelers that are suitable for spatial research. Both links should be bidirectional to ensure dynamic interaction between all components of the tool, a crucial quality because of the fast
Both students and researchers are assisted by a group of students that use this engine in their design process for their master’s thesis to try and find bugs and propose additional functionality. They are a first test group for the early versions of the tool.

Further research and intentions

Both cases are presently in full development. For the design studio, the staff recently formulated the intention of reforming the staff from the present rather homogenous group towards a similarly heterogeneous team as proposed for the students. This will again introduce more different perspective and specific expertise to the design process.
Once a fully functional tool is ready, the design studio will be an interesting beta-testing group. The effect of using the tool in a real design environment will be investigated further. Remarks and proposals from this test group will then again be incorporated in the further development of the tool.
On of the next functionalities to be incorporated in the tool is producing technically correct drawings and schemes from the simply ‘massed’ model and all additionally ‘labeled’ information.

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