International Journal of High-Rise Buildings
December 2014, Vol 3, No 4, 279-283

International Journal of
High-Rise Buildings
www.ctbuh-korea.org/ijhrb/index.php

A Methodological Shift in Building Design through Development of Collaborative Design Platforms

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Abstract

This paper introduces two platforms created by the development team at CORE studio, Thornton Tomasetti's global innovation studio. Collaborative platforms change the way that parties communicate and develop projects. Wikipedia is one of many great examples for a platform that supports collaborative development of a product - the world's largest encyclopedia. In the AEC industry, no such platform exists that can be used for collaborative development of a building project, and hence, information exchange between the parties involved, and modeling programs used in a project is slow and opaque. The platforms introduced in this paper allow for much greater transparency at all stages of the building design process, and hence improve the flow of information between parties involved in the process, both firm-internal and external. While traditionally, the use of a large number of different modeling and analysis platforms is hard to manage by a project team; this paper introduces methods that strengthen the design process by using a multitude of programs needed in the different building design phases.

Keywords: Collaboration, BIM, Big data, Engineering, AEC, Revit, Grasshopper, API, Web, Technology, Github

1. Intro

Collaborative platforms change the way that parties communicate and create projects. Wikipedia is one of many great examples of a platform that supports collaborative development of a product. It is the sixth most popular website globally (www.alexa.com, 2014) and constitutes the Internet's largest and most popular general reference work (Tancer, 2007). Most people with access to the site can edit almost any of its articles (Wikipedia contributors, 2014). Google Docs is another example for a platform that enables collaborative editing of documents (Wikipedia contributors, Wikipedia, 2014). Multiple people can edit text documents, spreadsheets or presentation files simultaneously, and use the built-in markup and revision tracking technologies to manage the documents. A growing number of innovative teachers use Google Docs to communicate with their students, and even replace the traditional whiteboards in the classroom with collaboratively edited Google documents (Lapowsky, 2014). GitHub is a platform that allows for collaborative writing of computer software, much of which is open-sourced for collaboration between otherwise unassociated individuals. It is used for project planning, staffing, time management, and, just like Google Docs, features tools for revision tracking, software change management, and other project management features.

What all these platforms have in common is the ability to enable multiple contributors to shape a cloud-hosted product such as an encyclopedia, an open-source software project or a spreadsheet together, over time, while managing revisions and communication between the parties. By providing transparency, and by offering a change-tracking and review process, these products can be developed at faster speeds, to higher accuracy, with instant access to more information by more collaborators. A Wikipedia entry, for example, can be edited and updated over years, and revisions can be made by different contributors within seconds.

In the AEC industry, no such platform exists that can be used for collaborative development of a building project. AEC professionals still heavily rely on the combined use of email, FTPs, markups, change orders and meeting minutes for the communication of information throughout the design process. Autodesk, Gehry Technologies and others are attempting to fill this need by introducing sharing platforms such as BIM360 and GTeam, but in addition to software vendors offering solutions, it greatly depends on the AECO firms themselves to push for improved methods of collaboration (JBKnowledge, 2013) - both internally with their colleagues, and externally with their clients and consultants. In recent years, we have seen AECO firms establish internal research and development groups that focus on developing custom solutions for their colleagues. This paper discusses two of these solutions;

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[1]https://github.com
[2]http://www.autodesk.com/products/bim-360/overview
[3]http://www.gteam.com/

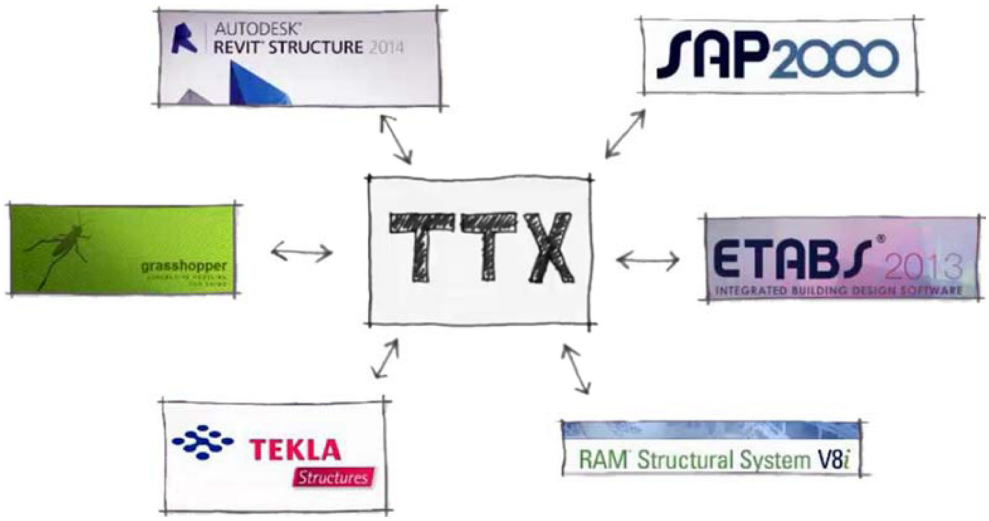


Figure 1. TTX - Bi-directional BIM exchange platform by Thornton Tomasetti.

one for internal collaboration, and one for external collaboration, developed by Thornton Tomasetti's CORE studio.

2. Outline

2.1. A BIM platform for internal collaboration and project management

With the proliferation of structural BIM software solutions, the interaction of the multiple analytical and modeling elements has become an essential focus for large structural engineering firms, which utilize a broad range of software tools in parallel. There is no software solution that can accomplish all modeling and analysis tasks; some programs are better for iterative 3D geometry modeling at the conceptual design phase; some are better to design the concrete systems, while others are needed to calculate steel structures. For documentation of the construction and the fabrication models, yet another set of tools is needed. Typically, these programs don't talk to each other very well. A fabrication model contains different representation for elements than a wireframe-based analysis model, and the industry has not enforced the use of a universal language, or translator, between these different programs. As a firm involved in structural engineering of new buildings, Thornton Tomasetti utilizes a number of programs on a regular basis, including Revit for drawing documentation, Tekla for steel fabrication modeling, SAP, RAM and Etabs for structural analysis, and, depending on the complexity of the building design, Rhino/Grasshopper for generation of the geometry.

One attempt at this interoperability issue is the development of buildingSMART's Industry Foundation Class (IFC) 2X4 in the last decade. While the industry made great progress in this space in recent years, especially with the introduction of IFC, the gains made have been more technical than cultural. Although the ability exists to translate an analytical model into a fabrication software package, it does not fundamentally change the way an engineer and a detailer design a project together.

Thornton Tomasetti Exchange (TTX) was created to increase the portability of data between above mentioned platforms, reducing redundancies, allowing a seamless flow in which each software tool can be used to its maximum benefit. The purpose of TTX is to provide a platform that enables a new type of collaboration during the design process - one that allows for real time, cross-platform updates of project information (see Fig. 1); and thus mimicking the abilities for collaboration enabled by GitHub, Google Docs and similar platforms.

A strong disconnect typically exists between the design, analysis and documentation stages of a building during the conceptual design phase. Traditionally, engineering does not begin until the design has been completed; and subsequently, the documentation process of the analysis results is not started prior to knowing all of the analysis results. In recent years, tighter timelines have forced these stages to overlap, resulting in replacing large portions of the analysis and documentation models, as the design updates

[4]http://www.autodesk.com/products/revit-family/overview
[5]http://www.tekla.com/us
[6]http://www.csiamerica.com/products/sap2000
[7]http://www.bentley.com/en-US/Products/RAM+Structural+System
[8]http://www.csiamerica.com/products/etabs
[9]http://www.grasshopper3d.com
[10]http://www.buildingsmart-tech.org/specifications/ifc-releases/ifc2x4-release/summary

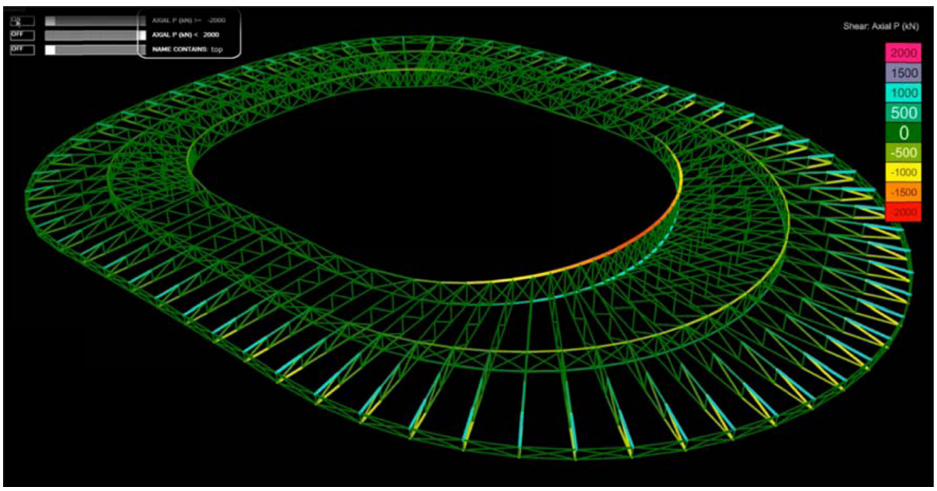


Figure 2. The TTX Query App allows highlighting BIM elements that match a certain criteria.

over time. Whereas other translation workflows, such as those enabled by DXF or IFC, do not allow the documentation process to proceed efficiently until the engineering analysis and design is complete, TTX allows multiple users to progress in parallel and to synchronize models at any point. Thus, a documentation model can be started prior to the design and analysis being complete. As the analysis of the project further informs the Building Information Model, the tags, notes, dimensions and other information on already produced drawings can be updated seamlessly, rather than being replaced. This allows engineers to be involved earlier in the design process, and stay involved until much closer to the project deadlines - while the creation of the BIM can begin earlier in the process of each design phase. Moreover, connection detailing models that are created in programs such as Tekla, can be informed directly by the results retrieved from structural analysis models.

TTX utilizes a database on the backend, which stores every piece of information that is exchanged between the programs over time, allowing the users to keep track of each project revision. Every time a project is synced to the TTX database from any of its currently supported programs, a new database entry is added to the TTX project. This entry contains information about the application that synced to the database, such as the sync date, user name and a mandatory user-defined message describing the latest change. It might look something like this:

- User: KMurphy
- Software: Revit 2014
- Sync Date: July 07, 2014, 11:15:23
- Message: Added roof to the model and modified grid lines 1 to 10

In addition to the above mentioned information about the authorship of a specific model instance, TTX keeps track of every element that was created, deleted or modified, in any of the applications. By having the transparency that comes with tracking every change, a user can revise the project, as it evolves over time, and always find information about which changes were made when, and for which reason. This information allows for easier coordination between the various parties involved, and helps to better identify potential errors in the process, such as those which can be discovered when comparing two models created in different programs. Moreover, this greater level of transparency enables a new learning process, by which one can analyze the steps taken, and the results thereof, to make more informed design decisions in the future.

A variety of apps is being developed by CORE studio to interact with the data contained in a TTX model. For the reasons mentioned above, a Revision History App was created that allows project managers and all engineers and modelers involved to review how the project evolved over time; which program was used to make which change, and by which user. Additionally, through this tool, models can be reverted to an earlier phase; and different states of a project can be visually compared in a 3D environment.

Traditionally, BIM applications are good at visualizing information about attributes such as materials used, finishes, weights and such. Analysis programs, on the other hand, are good at visualizing analysis information, such as forces acting in elements, by color. The information stemming from a Revit model is very different to that stemming from a SAP file of the same project. But it is not common for a program to represent views for these different types of data. Information that is captured in the TTX database stems from both BIM platforms and analysis platforms - thus, a custom app was developed to enable querying of the TTX data in meaningful ways (Fig. 2). For example, the user may choose to color code all elements that are rotated off 90 degrees, as well as all elements of which the end forces are greater than a certain threshold. It is important for engineers and project managers to over-

lay these different sets of data, because analysis information typically directly informs BIM information.

A further app that is currently being developed is a web-based model viewer, which allows project managers and collaborators from other firms to review and overlay the different datasets attached to a TTX file in a web browser, allowing for greater transparency between parties involved in the design process.

TTX is an example of a platform that entirely changes how engineers, modelers, project managers and external parties shape and define a structural BIM project over time.

2.2. An automated design-feedback approach for architects and consultants

Another example - one for improved teamwork between engineers and architects at the conceptual design phase - is the Remote Solving platform. Traditional collaboration processes between designers and consultants suggest a sequential process of design, then evaluation - rarely allowing for analytical feedback to better inform the design of a given project. Consultants are typically asked to join project teams after major design decisions have been made, when there is limited time and design flexibility for the consultant's feedback to be studied or implemented. In recent years, we have seen a shift, as design teams are looking to bring consultants into projects earlier in the exploratory design process to maximize the ability to enhance the performance of the building. Even though involving the consultants in the early stages of the design can potentially benefit the project, it does not guarantee a successful collaboration if the feedback from the consultants is not both timely and comprehensible. This calls for the intelligent design of a new means for exchanging information that will nurture a successful collaboration - and a change in how collaboration must occur to be relevant.

The traditional process of setting up a simulation model, running the analysis and preparing a report rarely keeps pace with the rapid progression seen in the architectural design process. With frequent architectural design changes, the analytical results prepared by the consultant are too often created for schemes that are no longer being considered. While the intention of the collaboration is thoughtful, the analysis often does not arrive in a timely enough manner to effectively inform the design solutions.

Thornton Tomasetti's CORE studio developed an innovative design process, Remote Solving, which diminishes this lapse in process by providing real-time feedback to designers based on accurate analysis.

This is achieved by establishing a workflow for automating the process of receiving frequent design changes from the architectural team and returning automated and meaningful results to the designers utilizing cloud-based computation. This concept can be applied to the various sorts of building analyses required in the early design phase. As a result, as the design team iterates through various options, engineering feedback is immediately returned. This process may happen over the course of minutes or through the duration of an entire design phase. Yet, what it enables at both ends of the spectrum is real time feedback on the implications of a particular change to the building's design - thus allowing a more informed process resulting in a more intelligent solution at the end.

In the most recent example, Thornton Tomasetti engineers were asked to study how ceramic frit patterns on a tower's facade impacted the amount of daylight entering the building. A remote solving process was established, that allowed the client to manipulate the pattern at their will, upload images thereof to a cloud directory, and, within an hour, receive a full report on the daylight performance of that particular design scheme. This process eliminated the days - or even weeks - it can take for consultants to receive a design, process it into a format for analysis, run simulations, prepare a report and return it to the designer. Unlike the traditional process, remote solving can easily keep up with the fast-paced iterations that often occur in the early stages of design. By utilizing computer power for communication a design team can successfully validate infinitely more options than what would be possible through standard means of communication.

2.3. Case study: An automated design-analysis-workflow for a frit pattern applied to the façade of a high-rise building

The diagram below (Fig. 3) explains the above mentioned process, this time using the Dropbox file sharing service to receive and deliver content. The back end of this model (in Grasshopper) runs a useful daylight illuminance (UDI) study using the open-source toolset Honeybee. The Grasshopper definition listens for new files in the Dropbox, loads them into the model, parses the images to create different glass types to approximate the transmittance of glazing that the frit pattern produces, runs the study, uses custom components to produce a rendering of the model, and finally generates custom formatted reports of the daylighting study results.

3. Conclusion

A number of collaborative cloud based platforms exist for tasks directly and indirectly related to designing and constructing a building, though the adoption thereof is slow for the AEC industry. By engaging a project-internal research and development team to explore new workflows and concepts, barriers to the adoption of new technologies and processes can be overcome more effectively. Many of

[11]http://patternguide.advancedbuildings.net/using-this-guide/analysis-methods/useful-daylight-illuminance
[12]http://www.grasshopper3d.com/group/ladybug/forum/topics/update-happy-yalda

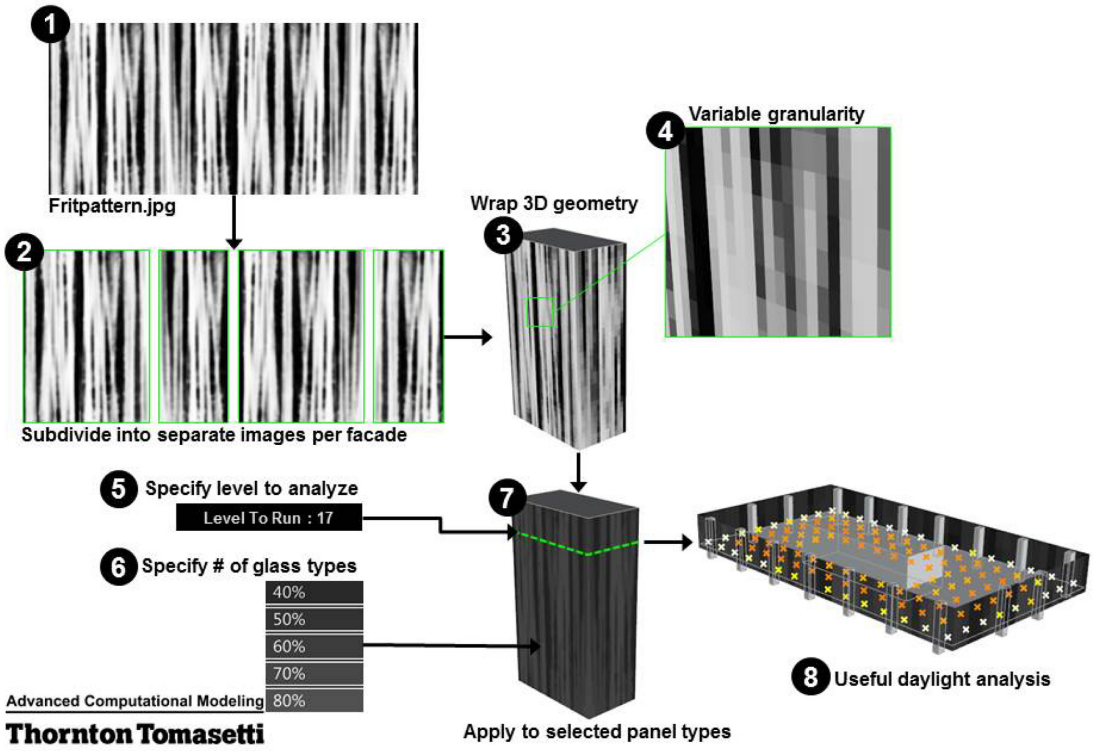


Figure 3. Process diagram of automated cloud-based analysis and reporting process.

the BIM and analysis related programs that are being utilized for the design, analysis and documentation of complex buildings can be partially automated by accessing the respective Application Programming Interface (API) of these programs. Thus, customized solutions can be created by design firms themselves, which enable better collaboration between parties involved in the same project. As cloud-based technologies become more available in the AECO industry, it is expected that these adoption rates of workflows such as the ones described in this paper will grow significantly. In addition to a change in technology, a cultural shift is necessary - and the openness for sharing knowledge, as embraced by collaborators to Wikipedia or open source software projects, will need to be encouraged in the AECO industry.