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5aAAa8. Interoperability Building Information Modeling and acoustical analysis software - A demonstration of a performing arts hall design process

Sunyoung Kim*, Robert C. Coffeen and Paola Sanguinetti

***Corresponding author's address: Architecture, University of Kansas, 1465 Jayhawk Blvd., Lawrence, Kansas 66045, sunyoungkim@ku.edu**

By sharing and managing the database for a building model, Building Information Modeling (BIM) facilitates the design process at less cost. Some of BIM software has capabilities for acoustical analysis, but it is limited to noise level demonstration of MEP system in a building. Sophisticated acoustical analysis programs, such as EASE and CATT provide the useful parameters to determine the sound quality of a space with graphs, A/V systems, material database, and auralization. This research explores how BIM with discipline-specific data reinforced with acoustical information will be beneficial to both architects and acousticians, by allowing them to communicate efficiently. The design process for a performing arts hall is used to demonstrate how to interoperate between BIM system and acoustical analysis programs. Revit Architecture and EASE program are used as design and analysis tools for the project. A model is developed to improve the process of embedding acoustic information in BIM and sharing knowledge in an integrated delivery process.

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INTRODUCTION

Building Information Modeling (BIM) software provides a central information platform to support the integration of analysis data from different disciplines. Architects, engineers, and contractors are actively involved in the building design process by using BIM software, such as Revit products, ArchiCAD, Bentley Applications, Vectorworks, Navisworks, and so on. Acoustical consultants started adapting BIM system in their projects with acoustical information from sophisticated acoustical analysis software: CATT-Acoustic, Odeon, and Enhanced Acoustic Simulator for Engineers (EASE).

This paper is to demonstrate how an acoustician can use BIM models with acoustical analysis information. The goal is to achieve a feedback loop between architectural design and acoustical analysis. This collaboration maximizes work productivity and coordinates work schedules between architects and acousticians. A case study of a performing arts hall design process is used to compare acoustical analysis results from different software and to develop a link between an acoustical database and a BIM model.

Revit Architecture is selected as the BIM software to build the auditorium model and to manage central information database. Ecotect is used to analyze acoustical data in the auditorium at an early phase design process. It provides an acoustical analysis calculation highly interoperable with Revit. Data from Ecotect is compared with data from EASE to understand advantages and drawbacks from different acoustical analysis tools. Revit MEP acoustical analysis tool is used to calculate the noise level generated by the HVAC system in the auditorium.

BIM ADVANTAGES

- BIM enhances work productivity
- BIM accelerates project delivery.
- BIM helps to coordinate and collaborate project teams.
- BIM creates central information in the project model.
- BIM optimizes schedules and costs.
- BIM facilitates building maintenance.
- BIM increases profitability and competitiveness.

BIM software enables the creation of three-dimensional design models that can integrate all the information pertaining to the project in a single data repository. The centralization of all the information helps project teams to perform a variety of complementary tasks including building performance analysis, visualization, construction document management, and improved accuracy of documentation.

Sharing design models and information promotes cooperation between architects and acousticians. The cooperation helps project teams to make quick and on-site decisions, and resolves design complications at the beginning of the design process. Early multi-disciplinary collaborations promote more-informed decisions throughout the project lifecycle.[1]

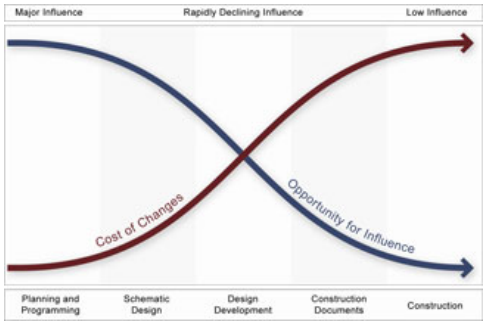

FIGURE 1. Cost of Changes and Opportunity for Influence throughout Building Design Process. The most cost-effective time to make changes is during the programming phase of architecture design process. . This phase of a project is the best time for interested parties to influence the outcome of a project. Figure adopted from ref. 1.

The architecture design process has four phases: programming, schematic design, design development, and construction document. According to the Whole Building Design Guild (WBDG), the most cost effective time to make changes is the programming phase. Integrated Project Delivery (IPD) is one of the project delivery strategies suggesting an innovative new contractual relationship with all the disciplines and emphasizing early collaboration on projects. BIM central information is a convenient tool, which makes this strategy possible. Knowledge-based design decisions through early collaboration enables a project to be more economic and competitive with less cost and more influence.[2] Architects, acoustical consultants, and owners can interact closely throughout the design process. They can understand that, for the best performance, all the building systems must be interdependent.

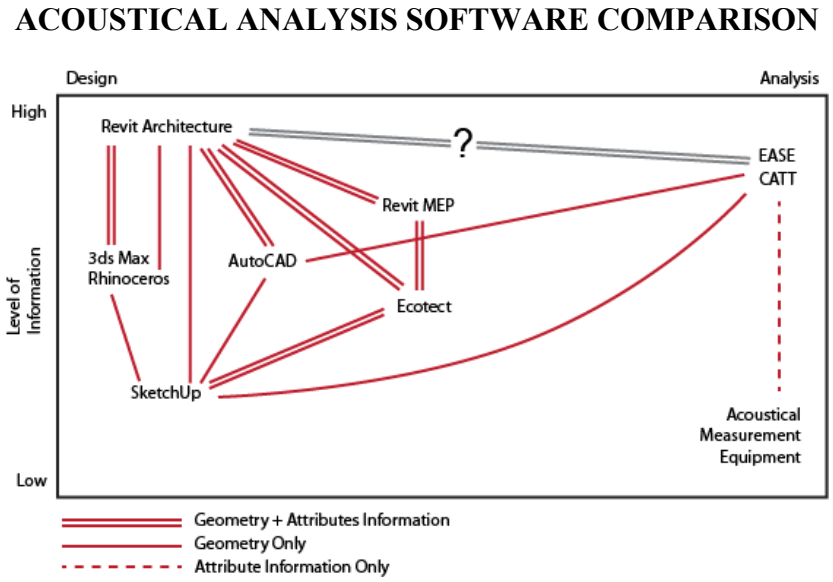

FIGURE 2. Interoperability of Design Tools and Acoustical Analysis Tools. Interoperability can be categorized according to the level of information while transmitting models between different design and analytical tools.

Acoustical consultants use field-specific analysis tools. Among various analysis tools, EASE software was used for an acoustical analysis for the case study on this paper. Although it provides sophisticated acoustical analysis for acoustical consultants, EASE is not interoperable with Revit products. Primitive design modeling methods in EASE requires acousticians to rebuild another project model in a separate file for their acoustical analysis. Modeling tools in EASE consume more time compared with Revit design tools to build the same project model. Thus, this workflow is not useful for updating new information to reflect feedback, and delays the speed of analysis deliverables. It also makes acousticians and architecture difficult to communicate as managing their models in a separate file.

Revit Architecture supports various design tools to improve project productivity, sharing the project model with other users. However, it lacks the analytical tools to estimate building performance. To supplement this information, it needs third-party analytical software. Thus, Ecotect is a building energy analysis software that acousticians should consider as an acoustical analysis tool to improve productivity. It is capable of calculating the building thermal analysis, the light analysis, and the acoustical analysis. It is also highly interoperable with Revit products using Green Building XML (gbXML) language. The gbXML file transferred material property and model geometry information from Revit to Ecotect, which is needed for building performance calculation.[3]

Acoustical analysis in Ecotect provides reverberation time (RT), sound decay time, and animation of sound ray tracings in a space. Although Ecotect has a limitation to get a full range of sophisticated acoustical information, it is useful to make fast deliverables when communicating with architect at the beginning phase of the design process, which demands fast feedback. Ecotect is also useful to empower LEED sustainability data in describing the efficiency of building energy performance.

In the case study, analysis results obtained from different acoustical analysis tools were integrated with a project model in Revit Architecture. The advantages and drawbacks of each acoustical analysis tool were studied to achieve a good sound quality of space that could satisfy acousticians and architects in the design process.

ONE CENTRAL INFORMATION PLATFORM

Central Material Database

Revit Architecture, Ecotect, and EASE have different material libraries. Even similar materials have different different acoustical properties. Sharing a material library database through the various software is necessary to provide consistent material properties for acoustical analysis. It increases project analysis credibility under the same given condition. The project model in this case study adapted the concept of the centralized material database that was editable and accessible externally.

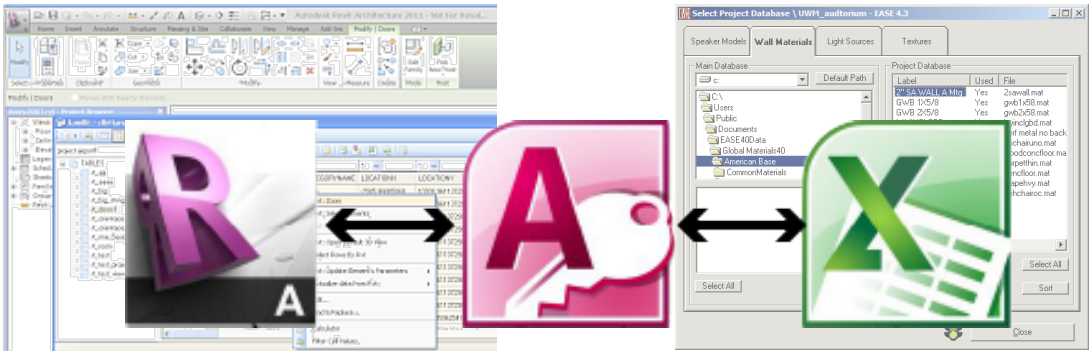

FIGURE 3. Revit Database Link to EASE Material Database. Material properties in EASE model updated the external material database, which connected to the model in Revit Architecture.

External material database links connects to the project model in Revit as Database Access. Materials used for project models in Revit Architecture synchronized with analysis software by using the central material database. These material libraries are customizable to add new materials, delete existing ones, or change the properties. The database linked to Revit Architecture loads customized information in material schedules and shares the information with other users.

Facility Management

Accessible information from one central information file in Revit Architecture is convenient for architects and acousticians to perform acoustical facility management. For example, if there is a management schedule about material life cycle and replacement information, acoustical consultants can serve better facility management under their responsibility and it can increase the firm's credibility to customers.

CASE STUDY – FLEXIBLE AUDITORIUM

This case study used an auditorium as an example that was a part of a whole project model. It had been submitted to a student design competition for reimaging America's national parks. For this competition, project team was formed to practice IPD strategy in collaborating students and experts from different disciplines. The project team designed an interpretive center, which included a visitor center, history museum, and event places. The author took charge of designing an auditorium and an outdoor event place. The auditorium, named Flexible Auditorium, was designed as a multi-purpose performance hall seating 400 people. It was designed to integrate the performance place with the outdoor event place.

For this case study, the author was in charge of bridging the acoustical knowledge gap between architecture students and architectural acoustics students. The author was also responsible for building the project models by using Revit Architecture and also combined all the information from different disciplines into one BIM file.

FIGURE 4. Flexible Auditorium Interior View. This auditorium integrated all the information through the design process in a single data repository.

Phase 1 – Programming

Early Acoustical Consultation

In this case study, initial acoustical calculations determined the volumetric size of the auditorium. The size guideline assured the proper reverberation time in the auditorium and helped the project team to explore different forms of the auditorium design. The acoustical knowledge at the programming phase of the design process helped the project teams to gain confidence when choosing the best design solution among the various design ideas.

Revit with Ecotect Analysis

Ecotect was used for the early acoustical analysis tool for this project. The values of the auditorium volume and the seating numbers were customizable in the Ecotect model to optimize the good reverberation time in the auditorium. Ray tracing animation helped the project team to understand the sound movement and to find the sound focusing spots in the auditorium. Simple but powerful visual demonstration by using Ecotect supported communications to develop designs as satisfying acoustical considerations.

Phase 2 – Schematic Design

EASE Analysis with Revit Model

In the schematic design phase, the project team arranged the overall design decisions and the material selection. It required the detailed acoustical analysis for the auditorium interior design. The auditorium model in Revit Architecture was exported to the DWG file for EASE software. The exported DWG file had only geometric information, so the team assigned acoustical materials in EASE after importing the file. The project team could discuss interior designs with refined analysis data from EASE. Material information determined in EASE updated the external material database, which linked to the auditorium model in Revit Architecture. This information also revised the material schedules and the material properties in the model.

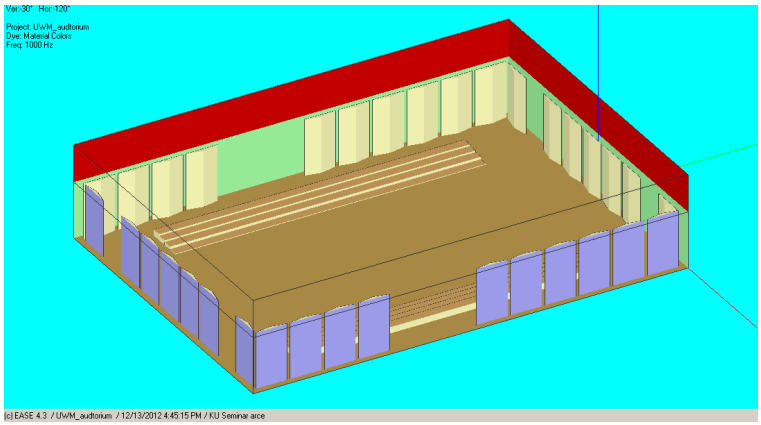

FIGURE 5. Auditorium Materials in EASE Model. Materials were applied to each architectural component in the auditorium to optimize the reverberation time in the auditorium.

Revit MEP and HVAC Noise Level

Revit MEP was used to layout the HVAC system running through the auditorium. The HVAC model in Revit MEP linked to the auditorium model in Revit Architecture. Acoustical analysis plug-in in Revit MEP estimated the noise level generated by the HVAC system. The noise level was used to enhance the noise isolation design and to reduce the noise transmission from the HVAC system to the audience place. Revit products were highly interoperable, so all the HVAC equipment schedules and the acoustical insulation materials in Revit MEP linked to the information in Revit Architecture. Automatic scheduling in Revit products eased the change made during the design process.

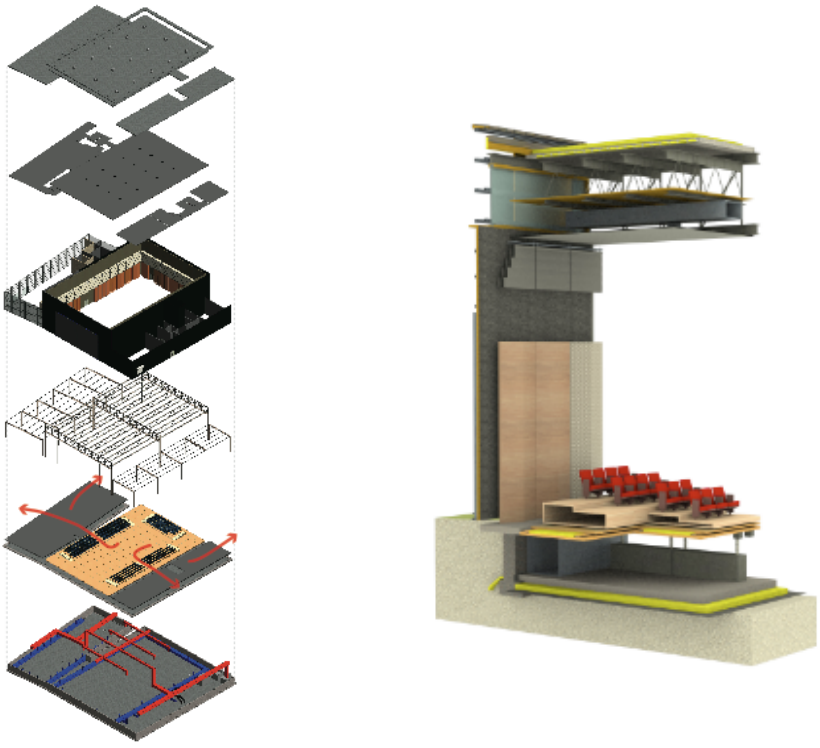

FIGURE 6. Exploded Axonometric View and Auditorium Wall Section. The HVAC system in Revit MEP was combined with the auditorium model in Revit Architecture. It allows the author to perform a variety of building performance analysis.

Phase 3 – Design Development

Auralization and Noise Reduction in EASE

In the design development phase, the project team agreed on the majority of design decisions. Detailed acoustical information from EASE strengthened the developed auditorium model. The information about the binaural impulse response, the noise isolation, the list of equipment for the sound reinforcement, and the auralization added to the model.

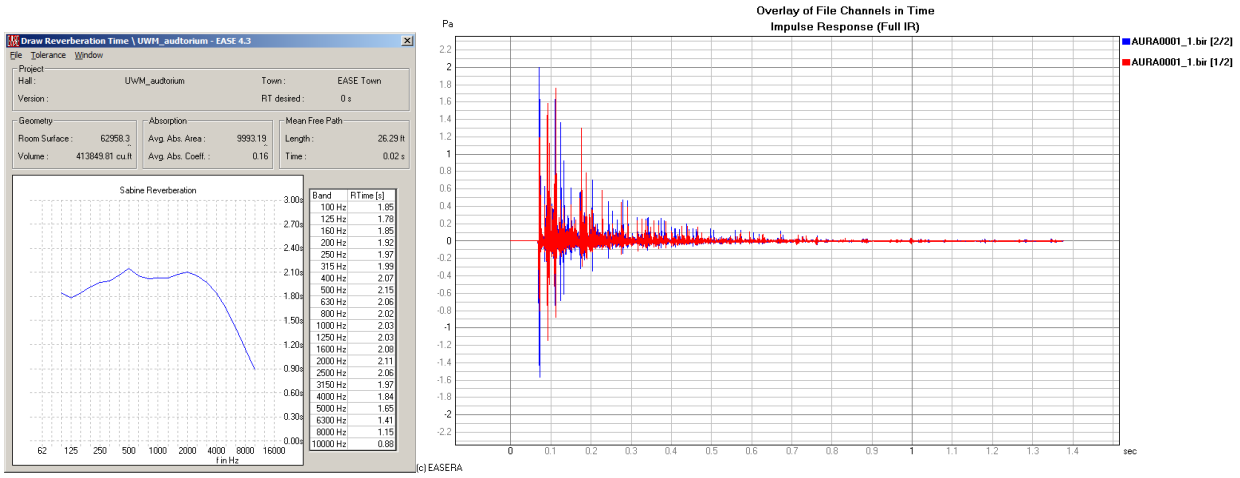

FIGURE 7. Reverberation Time and Binaural Impulse Response. Determined materials and dimensions of architectural components were placed in the auditorium model. Analysis data from EASE model was useful to estimate the quality of sound in the auditorium.

Sustainable Energy Analysis in Ecotect

Models in Revit Architecture were interoperable with Ecotect. The prompt responses to reflect design feedback increased time for more acoustical analysis to make a smart design decision. Although there was a limitation of the acoustical analysis in Ecotect, it was apt to produce useful analysis results without consuming time to rebuild the project model for the acoustical-specific analysis software.

Ecotect imported the building information from Revit Architecture by using the Green Building XML (gbXML) file. The gbXML is a schema or "language" that allows BIM authorizing software tools such as Revit products to communicate with building analysis tools. The gbXML file is the type of information for the building energy analysis that includes thermal, physical, and acoustical information.

3ds Max for Rendering

The project model in Revit Architecture linked to the FBX file, which contained material appearance information for computer rendering software, such as 3ds Max. During this design process, the modified information in the model revised the geometry and the material information of the linked FBX file. The FBX file changed the rendering results in 3ds Max. The project team could frequently checked the realistic design appearance of the auditorium by rendering the model in 3ds Max. Thus, the project team could make aesthetically and functionally good decisions for the auditorium by changing the texture and the color of the auditorium materials, which had the similar acoustical properties to keep the consistent design sound quality.

Phase 4 – Construction Document

Post-rendering Process

Final rendered images after reflecting aesthetic considerations at the development phase were polished by using the post-rendering tools: Photoshop and Illustrator. One well-rendered image was worth a thousand words to deliver the project team's design intents for this auditorium.

One Central File & Detailed Construction Document

One central file in Revit Architecture integrated all the information through the design process. The project team could eliminate time to collect scattered information from different disciplines. The project team could also easily extract useful information to make the construction documents: the site plan, plans, sections, detailed callouts, perspective interior or exterior views, rendered images, structural or material schedules, facility management schedules, and so on.

CONCLUSION

BIM continues to grow and develops tools to improve project productivity. This paper proposed a methodology whereby architects and acousticians could collaborate with their professional tools. I looked forward to providing an exemplary workflow to maximize the work efficiency of collaboration and to minimize iterative modeling process for acoustical analysis tools. On the extent of the interoperable acoustical performance analysis, Ecotect was introduced as acoustical analysis software to produce useful analysis results.

The central information platform in BIM system enabled the project team to share knowledge and to collaborate with experts. Early collaboration in the architecture design process facilitated knowledge-based design decisions to make the building performance better. The central information in the project model was more flexible to reflect design updates and to preserve the consistent design intent through the design process. The integrated information in BIM system increased the project team's design efficiency, the productivity, and the information quality in this case study.

Considering the interoperability of the BIM system with the acoustical analysis tools was worth the effort. More acoustical design guidelines were reflected in the design decisions of the auditorium. This led the project team to design the auditorium, which supported the high acoustical performance results.

ACKNOWLEDGMENTS

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