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The Rosewood experiment — Building information modeling and interoperability for architectural precast facades

Rafael Sacks [a,*], Israel Kaner [a], Charles M. Eastman [b,c], Yeon-Suk Jeong [b]

[a] *Faculty of Civil and Env. Engineering, Technion–Israel Institute of Technology, Haifa 32000, Israel*
[b] *College of Architecture, Georgia Institute of Technology, Atlanta, GA, United States*
[c] *College of Computing, Georgia Institute of Technology, Atlanta, GA, United States*

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ABSTRACT

The Rosewood experiment examined building information modeling (BIM) and product data exchange in the design and fabrication of architectural precast façades. The façade panels of a 16 story office building were designed and fabricated using traditional CAD, while a parallel workflow was performed independently using BIM tools. No limitations were encountered in designing and detailing of precast façade pieces with current software. Production of the same set of drawings showed a productivity gain of 57% over the CAD process. However, the data exchanges between architectural and precast engineering systems were incomplete and inconsistent, confirming the need for BIM exchange standards. The existing Industry Foundation Classes schema (IFC version 2x3) lacks precast-specific entities and property sets. The majority of the difficulties can be traced to a loss in translation of semantic meaning for the objects exchanged.

1. Introduction

Building information modeling (BIM) is a conceptual approach to building design and construction that encompasses three-dimensional (3D) parametric modeling of buildings for design and detailing and computer-intelligible exchange of building information between design, construction and other disciplines. Development and products supporting integrated 3D parametric modeling have matured so that its adoption is becoming widespread as the base technology for building information development and management by major architectural and engineering firms [1]. As implementation in industry spreads, the pressure to make progress on the second aspect, that of interoperability, grows [2]. The second aspect of BIM utilizes the object model data generated to support improved processes throughout the building life cycle. The Rosewood project experiment addressed workflows between design and construction. It was undertaken to provide the workflow knowledge and data-use definitions needed for the preparation of a BIM standard for the domain of architectural precast facades. The domain of architectural precast relies on engineered- and fabricated-to-order panels that have complex geometry and detailed fabrication and erection issues. Its fabrication and erection require close collaboration among architects, precast fabricators, structural engineers and general contractors. The experiment also enabled detailed measurement of expected future productivity gains.

A building product model schema, which defines the data structure of objects, attributes and relationships, is the foundation for effective exchange of building information between disparate software applications. The Industry Foundation Classes (IFC) [3] and CIS/2 [4] schemas are the leading examples of product model schemas for building construction [5].

However, a building model schema is not sufficient in and of itself to transfer and share building data; additional building information modeling standards are needed to prescribe what subsets of a project's information must be exchanged at any step in a project workflow in order to fulfill the parties' information needs, and which objects and attributes are to be used in each exchange to represent that information [6]. The Facilities Information Council (FIC) of the National Institute of Building Sciences in the US is coordinating development of national BIM standards (or 'NBIMS') [7] for this purpose. These standards will provide guidelines for software vendors in developing translators that use the same subset of the IFC schema in a uniform way and will guide construction professionals in the way they use their BIM tools to compile models that can be exchanged effectively. They have a secondary effect of defining very function-specific information that the BIM design tools need to provide, in order to populate the data needed by the other applications. The Rosewood experiment was part of a broader research project led by NIBS which culminated in preparation of an early Information Delivery Manual (IDM) [3] within the NBIMS process.

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* Corresponding author. Tel./fax: +972 4 8293190.
E-mail addresses: cvsacks@technion.ac.il (R. Sacks), israelkaner@gmail.com (I. Kaner), Charles.Eastman@coa.gatech.edu (C.M. Eastman), yeon-suk.jeong@gatech.edu (Y.-S. Jeong).

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The goals of the experiment were to: (1) explore what can be achieved with the use of 3D BIM tools in collaboration between architects and precast façade fabricators given existing tools and exchange capabilities; (2) identify appropriate collaboration workflows for design and fabrication of precast architectural facades where the precaster is a subcontractor, and the improvements in information exchange requirements that will be needed to support them; and (3) record the processes and productivity achieved in parallel 2D and 3D workflows for the same project. The primary research method was 'action research'; the second author spent two months in residence at a precast company's design department modeling a 16 story office building (the 'Rosewood' building) using BIM tools in parallel with the actual design and detailing of the same building using CAD tools by a major architectural firm and a separate precast fabricator.

This paper is structured as follows. After a review of the state-of-the-art in interoperability for building construction and parametric modeling for the domain of architectural precast, the following sections present the goals, method and results of the experiment. Lessons learned concerning collaboration between disciplines, appropriate workflows in this domain using BIM and software limitations encountered, are described and discussed. The conclusions concern issues of BIM standard development, the nature of collaboration using building models, productivity impact measures and ongoing research needs.

2. 3D parametric modeling for precast concrete

The building design community is in transition, adopting and learning to effectively utilize a new generation of parametric 3D modeling tools. These include Revit Architecture[1] [8], ArchiCAD [9], Bentley Architecture [10] and Digital Project [11]. The consistency of a single digital 3D building model, with associated data regarding functional, material and product information, leads to major changes and potential productivity benefits across a wide range of the construction industry [1].

In the precast concrete domain, two software packages are available for production detailing and preparation of drawings. Both grew from the research and development impetus provided by the Precast Concrete Software Consortium [12], focused on leveraging the three-dimensional parametric design approach [13] to integrate all aspects of precast concrete structure design, fabrication, and erection. These are Tekla Structures [14] and Structureworks [15].

Until now, there has been little effort to realize, test and evaluate the interoperability between the primarily architectural building design tools and the precast modeling software. Most architecture firms and precast concrete companies are hesitant to adopt fully BIM supported information exchanges, using advanced three-dimensional software solutions directly for their design collaborations in the absence of unbiased and credible demonstrations of their feasibility and value. In that architectural models are almost never made available to fabricators, precast companies are experienced in laboriously generating the 3D models internally by interpreting the two-dimensional drawings provided by architects. During the regeneration process, problems resulting from data replication and inconsistencies and misreading often occur. On the positive side, data regeneration requires the modeler to systematically examine all aspects of the project from a buildability and erection perspective making corrections during the replication process.

There is gathering evidence that even this inherently inefficient process provides distinct advantages over a traditional two-dimensional process. Sacks et al. [16] established a target benchmark for improved productivity in design and detailing of architectural and structural precast concrete leading to a reduction in overall project costs of 2.3% to 4.2%. Data collected recently covering four separate projects has shown that the productivity benefits for drawing production alone using this process are in the order of 20.3% to 47.4% [17]. Given the benefits of 3D modeling even with minimal interoperability, it is clear that direct migration of the architectural model into the precast concrete programs will allow the delivery of building information to be far more rapid, flexible, efficient, and economical than is possible today.

3. Development of building information modeling standards

The internationally accepted approach to achieving software interoperability within the architecture, engineering and construction industry is based on the ISO-10303 Standard for the Exchange of Product model data (STEP) [18]. The STEP standard procedure begins with elicitation and collection of information requirements. It defines the scope and processes to be supported by developing a process model of the domain, called an Applications Activity Model (AAM). The AAM serves as the basis for defining the scope of an Application Requirement (or Reference) Model (ARM) in various graphic and non-graphic data modeling languages such as IDEF1x, NIAM, EXPRESS-G, or EXPRESS. An Application Requirements Model is basically a data model for products which is identified by experts in the industry; it is a "detailed specification of the data objects (entities and attributes) and the relationships between them that are required to support the activities within the scope of the industry application" [18]. This is called the logical (schematic) data modeling phase. The ARM is then interpreted, refined, elaborated, and integrated on the basis of integrated resources (IR). The IRs are data models that reflect and support the common requirements of many different application areas of product data. The integrated model is called an Application Interpreted Model (AIM). The IFC model [3] is an AIM, and is written in EXPRESS language [19].

However, availability of an IFC product model schema does not provide a sufficient condition for interoperability. BIM software applications serve a variety of purposes (such as model compilation, structural/thermal/acoustic analysis, fabrication detailing, visualization, production management, etc.) and their internal building data representations are each different, suited to their own functional needs. Also, multiple ways are provided for modeling the same information. Currently, each vendor must decide on an appropriate mapping between the internal representations of their application and IFC entities and attributes when preparing export routines to IFC files. Similar ad hoc assumptions must be made by the import translation writer. The result is that without further standards specification, there is little uniformity in the content of IFC files, making exchanges unreliable and unpredictable. The mechanism proposed to overcome this difficulty is the preparation of standard product model schema views, termed 'Model View Definitions' (MVD), for the wide range of different exchange scenarios, as well as modeling guidelines, so that vendors can develop translators that provide uniform and predictable data in a mutually agreed way for each exchange. There are called BIM standards.

The overall outline for development, implementation and deployment of a BIM standard is shown in Fig. 1. The first steps are to coordinate formation of an industry task group, to elicit the domain knowledge of both the product and process aspects of the exchange requirements, to formally model the business processes, and to prepare an IDM for industry review. The following steps (shown as the 'construct' step in the figure) are technical in nature, focusing on information and software engineering: development of MVDs and specifications for software implementations, and definition of missing IFC objects, property sets and relationships. The process includes both the formal process to incorporate new IFC definitions in the internationally recognized IFC schema as well as implementations of model view software translators by BIM vendors. The final tasks

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[1] Formerly Revit Building.