BIM-fest

A Town+Gown Symposia Event

New York Public Library Branch @ 455 Fifth Avenue

January 23, 2013 (8:30 a.m. to 10:30 a.m.)

What is BIM? Building information modeling (BIM), the most recent iteration of computer-assisted design, has opened the window on design possibilities while permitting cost avoidance and schedule and cost containment, if not reduction, while maintaining quality.[1] BIM originated from parametric solid modeling (PSM) software used earlier in the automotive and aerospace industries. As these software platforms evolved and become less expensive they migrated, as BIM, into the field of physical structures. PSM/BIM programs can hold large amounts of data—spatial, schedule and cost—permitting users to explore various designs at the earliest possible stage as well as the inter-relationships among design, constructability, schedule and price. BIM links design element relationships, so that one change in a design automatically redefines all the relationships. A well-built model continually updates the design as information from the design process fosters change. With a larger market share and increased adoption in part due to increasing ease of use, custom user interfaces and common tools, BIM is becoming a routine practice tool at design firms.

Designers, working with other project participants as the service delivery methodology permits, can design, test and refine designs within the computing environment, early in the process, revealing conflicts that can be resolved before a shovel ever touches dirt. Resolving conflicts as early as possible avoids the higher costs of change orders during construction when change is more expensive. The BIM tool can turn the design process into a predictive process instead of the reactive process is has historically been

in the absence of technology, because BIM provides clear and accurate visualization of the project at all levels that can facilitate detailing and multi-material conflict detection. Further, the inevitable data loss or arbitrary changing of data that occurs in the conventional handing-off of drawings along the process is minimized in the BIM environment because all data resides in the model to which all participants have access. With BIM, the conventional and distinct stations of the process are smoothed into a continuous, less-differentiated process of *designengineeringlayoutproduction.* In a BIM environment, the design function, previously distinct from the construction function, melds seamlessly with the building process. Teams can produce drawings that represent the objects they want to build. And, as a not inconsequential related benefit,

[1] In an early expression of quality in public sector construction, I.N. Phelps Stokes, who presided over the Art Commission under Mayor LaGuardia, noted: "The production of beauty, especially by simple and inexpensive means is a very subtle problem and can be solved successfully only by a combination of ability, experience and care." This early expression of quality parallels value analysis theory which posits that the cost of a built thing is variable quantity dependent on function, durability and aesthetics. Several possible combinations exist along a continuum of prices. The interplay between the owner's prioritization of the project's function, durability and aesthetics and their costs forms the value exercise, which is ultimately bounded by what the owner wants and/or needs and is able and/or willing to pay. Value, the ratio of function, durability and aesthetics to cost, can be increased by either improving function, durability or aesthetics or reducing the cost or a combination of the foregoing. The formal value exercise, originating from World War II industrial production management techniques, seeks to identify the optimal combination of function, durability and beauty (the Vitruvian concept of "delight" or the contemporary concept of "build quality") within financial constraints. *See* Lawrence D. Miles, *Techniques of Value Analysis and Engineering*, 3rd ed. (1989) and Construction Task Force, *Rethinking Construction*, a report of the Construction Task Force to the Deputy Prime Minister, John Prescott, on the scope for improving the quality and efficiency of UK construction (1998).

BIM can function as an end-to-end management tool for coordination and control.

Further, the BIM modeling software can generate construction drawings, schedules, isometrids, walk-throughs, renderings, shop drawings and even output cut files to be used in off-site production of building components, further reducing project costs for a variety of reasons. By facilitating efficient off-site production of building components, BIM can increase the efficiency of factory features, such as robotics and automation, multi-modal material movement, and simultaneous production, because computer generated quality control documents travel with the components throughout the factory. The off-site production savings that result from reductions in land rents and labor costs due to on-site production can be counter-balanced, in a labor economics sense, by the incremental increase of projects in a BIM-efficient environment and the continued need for traditional skilled and semi-skilled construction labor at the factory, supplemented by an increase in technology workers required by BIM.

Public owners, such as the Government Services Agency in the United States, the Public Works and Government Services in Canada and, now, the New York City Department of Design and Construction (DDC), are pushing the use of BIM on public projects in the belief that use of BIM as early as possible in the process will reduce change orders and delays during construction. In the United Kingdom, public owners are on notice that, by 2016, government projects must be designed, constructed and operated in a BIM environment. Public construction jobs are increasingly including the requirement that subcontractors be "BIM-Capable", having staff with experience and competence in various 3-D computer-assisted design products, as a pre-condition to qualification on projects with significant complexity. This movement by the construction industry is not, however, as dramatic as it may appear. In the lifetime of many architects in practice today, the drafting table has gone from a functional item to an artifact one may keep in the office for its visual and historical appeal. Designers, younger and older, work on computers. Further, automated off-site production of building components aided by computer technology is not of recent vintage either. The "hand" assembly at job sites has obscured the steady evolution and expansion of off-site production that has been occurring for years. The economics of development and construction—the desire for complex and innovative iconic designs and the need to reduce costs by automation, will continue, as will the concomitant use of BIM on projects, including those that are publicly-owned and financed.[2]

DDC and BIM DDC released the *BIM Guidelines*,[3] the latest in its series of guidelines for consultants working on DDC's public building projects. The *BIM Guidelines* reflect DDC's efforts to bring BIM to bear on the public building design and construction processes in order to help DDC continue to deliver high-quality public building projects within budget and schedule parameters. Since BIM use, as a technology and as a process, on two pilot projects (discussed below) demonstrated improvements in project delivery, DDC plans to expand BIM use across its portfolio of projects, necessitating the development of the *BIM Guidelines* as one way to provide consultants with the means and processes to support their work on DDC's projects.

DDC's use of BIM and development of the *BIM Guidelines* arise from the collaborative nature of building design and construction "on the ground", the need for which is only increasing with the increasing complexity of modern built structures. Further, BIM's post occupancy functionality dovetails closely with the City's environmental sustainability focus on building performance and its financial sustainability focus on life cycle operations and maintenance. The *BIM Guidelines* represent standards that will evolve over time as BIM tools and practice evolve, for use on the City's wide-ranging portfolio of public buildings and by other public owners that do not have their own standards.

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[2] From November 17, 2009 DDC Talks, *Computer Modeling and Construction Practice: How Iconic Buildings Get Built,* Walter Koppelaar and Julian Bowron, Walters Group. The projects highlighted in this presentation were Toronto's Royal Ontario Museum expansion and the three-and-a-half story elliptical spiral steel stairway, clad in fiberglass, for the Tommy Hilfiger global flagship store on Fifth Avenue in New York.

[3] *See* http://www.nyc.gov/html/ddc/html/pubs/publications.shtml.

On September 13, 2012, DDC hosted a symposium to discuss DDC's implementation of BIM, how consultants should use the *BIM Guidelines* and what they should expect on public projects going forward. The presentation stressed aspects of BIM that promote collaboration and communication, such as access to the same design information by all project participants, eliminating the multi-step conventional process with the potential for breaks in communication of information. In addition, the *BIM Guidelines* include many BIM uses, all or some of which DDC expects to implement on a project-by-project basis depending on project characteristics. BIM facilitates better and earlier understanding of site/existing conditions and user needs, permits continuous feedback on building code compliance, permits identification of conflicts on the site and among the building systems, and can increase site productivity and safety, which collectively contribute to the avoidance of costs that accrue in the conventional process. BIM functionality in cost estimation and constructability begins in design and continues through the construction phase. BIM's functionality then can continue post-construction, providing opportunities for additional life cycle cost avoidance and optimum maintenance and operation of public investments.

At the Symposium, one of DDC's most complex projects served as the case study to provide an overview of the use and implementation of BIM and technology in the public sector.[4] Implementing BIM on two pilot projects stemmed from DDC's institutional proactive strategy of establishing structures and processes to ensure design quality while meeting budget and schedule goals. State law constrains the City, along with most public owners in the State, to use the segmented design-bid-build methodology, which creates temporal, contractual and functional divides between the designer set of entities and the constructor set of entities.[5] DDC, the construction manager for a significant portion of the City's capital program, must work within an environment where the design and constructor entities and functions are separated while fulfilling its Charter mission within budget, schedule and quality parameters. Since 2004, when the Mayor initiated the City's Design and Construction Excellence (D+CE) program, DDC has continually raised the bar on itself, establishing internal structures and processes to ensure that meeting budget and schedule objectives would not compromise design or construction quality. DDC has used a number of strategies and technology deployments covering all phases of project development, including the use of BIM, to deliver quality projects. DDC has implemented the full use of BIM, within a constrained statutory environment, on two complex projects: a LEED Silver-targeted consolidated training facility (the "Police Academy") for the New York City Police Department ("NYPD") and the new Public Safety Answering Center ("PSAC II") to augment and provide redundancy for the City's current 911 services.

In theory, BIM use, along with other strategies and tools,[6] would permit a public owner to improve productivity from design through construction, increase collaboration, coordination and clash detection, maintain or compress schedules, maintain or reduce cost estimates and reduce the frequency and type of rework and change orders. On the Police Academy project, BIM changed the way DDC, NYPD (the client agency and end-user of the project), and the design consultant and constructor entities interacted and used information. BIM provided greater transparency throughout the design-to-construction process, minimizing errors that could be identified during design, increasing productivity, and, ultimately, avoiding costs that would have been incurred in the absence of BIM. As a result of the empirical observations on the Police Academy and PSAC II projects, DDC has initiated several additional pilot projects using BIM to move to a digital review process, eliminating a complex paper-based process and providing a seamless ability to share and review the 3D models and multi-format data with all stakeholders, further improving collaboration,

[4] Caron Beesley, *BIM Meets the Big Apple,* http://www.dlt.com/content/bim-meets-the-big-apple-%E2%80%93-a-case-study-in-excellence.

[5] The constructor set of entities is a network of construction firms linked on a particular project by a network of contracts, typically with a general contractor or construction manager at the apex.

[6] One such strategy includes adoption of lean construction strategies and delivery methods.

conflict resolution, and planning—and avoiding certain costs—all before construction or renovation begins. On the Police Academy project, additional types of avoided costs were made possible with the transfer of the BIM model's virtual design to the construction manager during construction, which permitted the construction manager to use the BIM model for scheduling, logistics, and coordination during the construction phase.

Supported by the empirical evidence from the Police Academy project, DDC plans to expand use of the BIM technology earlier in the mandated transition from design to construction by making the BIM model available to potential bidders to provide them with more useful information to ensure more accurate bids. It would be expected that BIM-based models for coordination along with BIM-based traditional shop drawings submitted by constructor entities would lead to a reduction in change orders due to scope, conflict in the field and lack of coordination, as compared to projects using conventional processes.

Moreover, the information in BIM, including digitized building data, will improve and enhance completed projects during their life cycle operation and (much) later renovation, repurposing or demolition, in part, because the data is able to be shared over time and across multiple agencies on multiple platforms. DDC is planning to make BIM models accessible to onsite teams via mobile applications, making it easier for teams to monitor and adjust build conditions against design conditions. DDC is also planning a move from a traditional CD and paper-based offsite archiving model to a more robust and accessible electronic data archive model in which BIM project files can be quickly and accurately retrieved and referenced for future projects. The BIM Guidelines anticipate the post-construction use of the BIM model for multiple authorized end users to discover ways in which the model and technology can facilitate the City's ongoing building operation and maintenance protocols, and refine agency requirements and standards to leverage the enhanced capabilities provided by BIM for building operations and management.

Solving for Avoided Costs through BIM. In the first doctoral dissertation completed in collaboration with Town+Gown, Mei Liu, Ph.D., Department of Civil Engineering, NYU/Polytechnic Institute, conducted research in the context of the question *What Is the State of Building Information Modeling and Integrated Project Delivery in Public Sector Construction?* The goal of the research was to identify a methodology for public owners to utilize BIM technology and processes and implement principles of integrated project delivery (IPD), a complementary relational contracting form, within existing public construction statutory constraints and quantify resulting avoidable costs. After a survey of the origins and nature of BIM, public construction statutory constraints, elements of the design-build service delivery methodology that corresponded most closely to the BIM's optimality, Liu identified advantages offered by BIM technology and IPD principles consistent with the statutory environment and proposed a BIM/IPD implementation model, called integrated design-bid-build ("IDBB"). The IDBB model was the subject of a controlled experiment described next, the results of which, along with analyses of DDC change order data and application of Bayesian network methods, suggested a range of avoided costs on public sector work as the result of implementation of IDBB.

In the 2011 fall semester, NYU/Poly Department of Civil Engineering structured its Information Systems in Project Management Course (CE8303), in order to identify and document the information and skills needed to successfully implement BIM and four-dimensional fully integrated and automated project processes (FIAPP) that integrate BIM and all the other relational databases, during the construction phase of a public sector project. Additionally, this course served as a controlled experiment for Liu's research to identify, assess and document BIM's role in the additional context of cooperative problem solving among project participants in an IPD setting. For the first ten classes, student teams, acting in the role of general contractor, performed standard operations leading up to the bid process for a public construction project, using BIM and FIAPP programs, to develop bidding strategies, prepare preliminary bids, conduct project schedule and time cost trade off analyses, and prepare final bid submissions. The "winning" bid then formed the basis for the final five classes during which re-formed student teams of archetypal construction participants—owner, designer, contractor and major subcontractor—applied the principles of IPD and used BIM and FIAPP tools to resolve fact patterns representing changed conditions similar to those experienced "in the field". The documented student team experiences suggested that it is feasible to use BIM tools in the context of IPD principles in the public construction project setting, though existing public construction procurement laws will exert constraints that limit the full potential to avoid costs.

Liu focused her quantitative analysis on project change orders, which represent changes to a project's original plans and specifications, as well as to a project's cost, that the contract documents anticipate and provide for accommodation in some way. The actual costs of change during the construction phase are not simply derived from the incremental increased costs of extra labor and materials of the rework, but include disruptions from the rework that impair a project's labor productivity by rippling into the parade of constructor entities collaborating in the complex and ever-changing space they are creating. While BIM in the design phase can reduce the likelihood of some changes occurring during the construction phase, "earlier is cheaper" remains true during the construction phase, presenting opportunities for cost avoidance during the construction phase under IDBB.

Liu applied data mining techniques, such as neighborhoods, clustering and trees, higher level techniques of networks and rules, and statistics, to DDC's public building change order data to identify systematic relationships and patterns in the database and among variables. The analysis, described in detail in the dissertation, led to the conclusion that use of IPDD—or using BIM and IPD principles on a public construction project—would permit the public owner to avoid certain costs as compared to projects done without BIM and IPD principles.[7]

Questions for the Symposium Conversation.
Town+Gown's *Research Agenda* is organized around the five academic disciplines—Management, Economics, Law, Technology and Design—that comprise the recognized multi-disciplinary field of the Built Environment,[8] modified somewhat by combining the three engineering disciplines with architecture under Design and by adding the Geography discipline to cover issues related to the urban planning field. Issues for consideration and conversation at this BIM-fest symposium event are arranged below around these disciplines:

<u>Management</u>

BIM increases the likelihood of avoiding costs (≈ savings) in two ways: (1) designs in BIM make certain changes less likely during construction and (2) construction in BIM makes certain other types of changes are more likely to be detected earlier during construction. How can the capital planning and budget process take advantage of opportunities for cost avoidance (≈ savings), including those during the project's life cycle, that BIM makes possible?

Looking at construction as a production function from the lean construction perspective,[9] how can BIM:

- facilitate eliminating waste/increasing value on projects?

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[7] In a companion statistical analysis of the same change order data set, *"Project specific, driven based contingency estimating model in construction,"* Mei demonstrated the feasibility of developing a reference class forecasting model for estimating capital project contingency. It is feasible to apply probability theory to contingency estimating, evaluating the random nature of changes and various risk drivers and using historical cost data for specific project types, to identify levels of confidence that an estimated contingency amount will keep total project costs within the estimated project budget. Limitations with the data set, including a limited number of project types, a limited number of projects and distortions produced by prior recording practices, prevent immediate application of this particular model. This project, however, sets out the methodological steps to develop a model based on a larger data set not limited by such earlier practices, which has the potential to become an executable model. The relationship between contingency and change orders is also an area for future research.

[8] Paul Chynoweth, *The Built Environment Interdiscipline: A Theoretical Model for Decision Makers in Research and Teaching,* Proceedings of the CIB Working Commission Building Education and Research Conference 2006), http://www.lawlectures.co.uk/bear2006/chynoweth.pdf, pp.1-5.

[9] Glenn Ballard and Greg Howell, *What Kind of Production is Construction?*, Proceedings IGLC '98.

- identify aspects of fixed-in-place construction that are now, via BIM, appropriate for standard manufacturing processes (off-site fabrication of components currently fabricated on site)?
- facilitate increasing supplier integration among designers and installers, raw materials suppliers and fabricators?

Technology is a tool for management, but management *qua* management is both an art and a science. What lessons from the multi-disciplinary design optimization ("MDDO") experience in other industries can be brought to bear on BIM-enabled construction projects so that the technology succeeds as a management tool?

<u>Geography</u>

BIM has code validation functionality. What potential does this functionality have for urban planners inside and outside government and for built environment regulators?

<u>Economics</u>

To the extent BIM changes the nature of on-site and off-site production within a jurisdiction, how would that affect the economics of the industry and industry participants?

In a fully BIM-enabled construction market, what should be state and local government regulatory objectives? What would a state and local government regulatory matrix (via pre-emption and home rule concepts) look like to reduce regulatory complexity and promote competition within construction markets?

<u>Law</u>

BIM increases the likelihood of avoiding costs as described above under <u>Management</u>. What types of contract provisions in the design and construction contracts, under current law, would optimize the opportunities for cost avoidance (≈ savings) that BIM makes possible?

The "controlled experiment" class applied IPD principles in contract form, using standard AIA IPD contract provisions, to the relationship among the project team members' use of the contingency amount. To what extent is the controlled experiment's methodology permitted under current law?

State law limits the service delivery methodology to design-bid-build, with the construction contract(s) awarded to lowest initial price, separating the design from the constructor and limiting the potential for BIM to avoid costs on public projects. What changes to State law would permit New York public owners to fully exploit the potential to avoid costs on public projects?

<u>Technology</u>

Since there are many BIM applications in the marketplace, the *BIM Guidelines* do not require the use of specific software. Since, however, collaboration on projects is the goal, at some point the broader issue of interoperability will need to be addressed. What are some of the obstacles to interoperability? What can a public owner do to increase operability?

<u>Design</u>

Since BIM facilitates "cradle-to-grave" functions, from design to operations and maintenance to ultimate repurposing or demolition, how can BIM facilitate the design of structures that embody the principles of "long life, loose fit and low technology" and increase the chance that flexibility in building designs can meet conditions not anticipated at the time of construction?

The experience of MDDO in the aerospace industry illustrates a paradox of control—by embracing and integrating industrial design tools and sharing, if not relinquishing, "power" with the other disciplines and stakeholders during the phase traditionally thought to be the domain of the designer, the designer increased control over the design until the project's completion. How would the paradox of control play out on building projects?