IPD, BIM, and supply chain optimization

Bottom-line benefits of 3D-enabled lean delivery for AEC projects

By Samir Emdanat; Robert Mauck, AIA, P.E.; and Matthew Jogan, AIA

NOVEMBER 2010

IPD, BIM, and supply chain optimization

Bottom-line benefits of 3D-enabled lean delivery for AEC projects

By Samir Emdanat; Robert Mauck, AIA, P.E.; and Matthew Jogan, AIA

In traditional design-bid-build project delivery, workflows from preliminary design through construction closeout are linear. Paper-based documentation exchanges are sequential, and revisions cycle through the system until the design is acceptable — prior to fabrication and installation, though often after design documents are issued. Fast-track projects present a challenge to the linear flow and force specific tasks to proceed in parallel before their predecessors are completed, potentially causing rework. Under ideal conditions, design-bid-build can yield projects on time, within budget, and to the owner's satisfaction. The reality is, AEC projects are often fraught with wasteful practices that cause delays, cost overruns, and quality concerns.

On large-scale, complex projects, team members frequently work with incomplete or changing information that is both reliant upon and integral to other parts of the project. Under these conditions, linear workflows and sequential information exchanges become obsolete. Integrated Project Delivery (IPD) enables relationships to be structured so that work can progress in parallel across disciplines and organizational boundaries. In this alternative approach, project stakeholders — owner/operator, architect, engineer, builder, and subcontractor — form an integrated, collaborative team focused on delivering optimal results from an overall project perspective.

IPD presents project teams with new challenges, such as how to redesign workflows, share information, and collaborate on an iterative design process while eliminating waste and inefficiency (Emdanat and Christian, 2010). By viewing the project delivery system as a supply chain, project teams can optimize the system to achieve the best quality. An essential component of this lean system is an integrated, 3D-enabled design-to-fabrication process that facilitates design review and direct digital exchange among stakeholders.

This article defines IPD and the opportunities it presents, reviews best practices in AEC project supply chain optimization, explores stakeholder relationships in an integrated team, and discusses the benefits of a 3D-enabled lean delivery system for AEC projects. An in-depth case study illustrates how Sutter Health has applied IPD and lean delivery principles to build a $320 million hospital replacement in Northern California.

IPD and the project supply chain

The IPD Task Force, an interdisciplinary group sponsored by The American Institute of Architects California Council and McGraw-Hill Construction, developed this working definition of IPD: "Integrated Project Delivery (IPD) is a project delivery approach that integrates people, systems, business structures, and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication, and construction." (IPD Definition Task Group, 2007)

In practice, IPD brings together all key participants at the outset, from engineers and architects to fabricators and installers, creating a cohesive,

Instructions

The Professional Development Series is a unique opportunity to earn continuing education credit at no cost to you by reading specially focused, sponsored articles.

After reviewing the learning objectives below, read the Professional Development Series article and complete the quiz online at www.stagnitomedia.com/cedu. Quiz answers will be graded automatically and, if you answer at least 80 percent of the questions correctly, you can immediately download a certificate of completion and will be awarded 1.0 professional development hour (equivalent to 0.1 continuing education unit in most states).

Note: It is the responsibility of the licensee to determine if this method of continuing education meets his or her governing board(s) of registration's requirements.

Learning Objectives

After reading this article, you should be able to do the following:

- Understand how integrated project delivery (IPD) differs from traditional AEC project delivery methods, and the opportunities it creates for successful project implementation.
- Identify best practices in project supply chain optimization, and discuss how these practices contribute to a lean delivery system.
- Discuss the risks and rewards of the IPD approach for project owner/operators, designers, builders, and subcontractors.
- Describe the benefits of a BIM-enabled lean delivery system based on real-world examples.

Professional Development Series Sponsor

Bentley Systems, Inc.

cooperative team. Every team member has a say in how to do the job most efficiently and with the fewest errors. It is this level of highly effective collaboration among team members that distinguishes IPD from other delivery methods.

Working together, the integrated project team identifies and eliminates waste in the system — the project supply chain. According to the Supply Chain Council, a supply chain "encompasses every effort involved in producing and delivering a final product or service, from the supplier's supplier to the customer's customer" (Supply Chain Council, 2010). For an AEC project, this supply chain is comprised of the organizations, people, processes, information flows, technologies, and materials involved in the planning, design, implementation, and delivery of the project (Figure 1).

A project supply chain is designed to deliver a specific project, persists until the project is completed, then disbands. In this respect, it represents a unique opportunity to design efficiencies into the system from the beginning. The supply chain can be organized, managed, and optimized. The challenge for the AEC team is to override the linear structure and thinking inherent in the traditional delivery system, and create an integrated structure that supports a collaborative process.

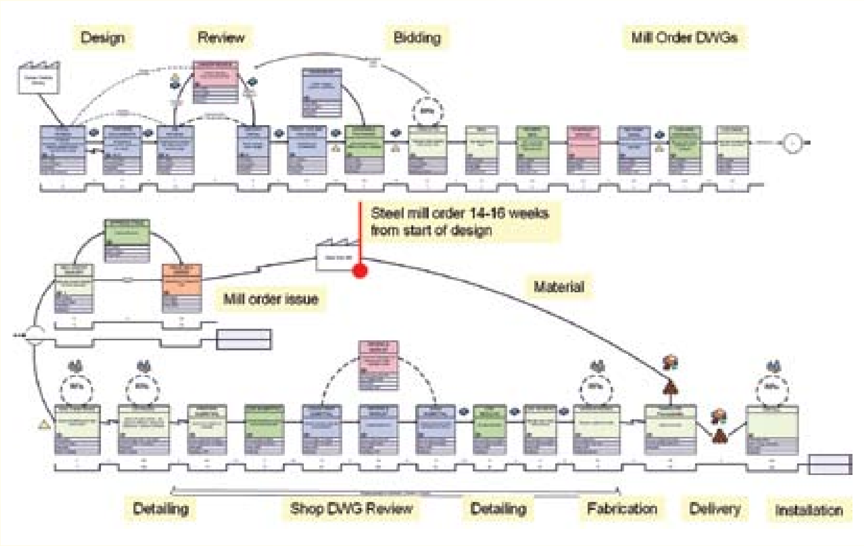
In addition to the opportunity to optimize the project supply chain, IPD presents opportunities to make the system more predictable and, at the same time, more entrepreneurial. The Lean Construction Institute identified "Three Linked Opportunities" associated with IPD. Each of these opportunities contributes to optimizing the project as a whole rather than optimizing its individual parts (Mauck, Lichtig, Christian, and Darrington, 2009):

- **Impeccable coordination** — Creating predictable workflows among disciplines and trades with the explicit goal of engaging specialty contractors early in design, improving product quality, and ensuring constructability.
- **Projects as production systems** — Changing the structure of the design-build process to improve system performance through parallel design, modularization, off-site fabrication, and multi-trade construction stages.
- **Projects as collective enterprise** — Using incentives to encourage collaboration across traditional boundaries (designer, builder, tradesman) so that team members function as an entrepreneurial unit rather than as competing entities.

To take full advantage of these opportunities, project leaders must embrace enabling technologies such as Building Information Modeling (BIM), direct digital exchange, design-to-fabrication, advanced project planning, and team collaboration systems. The IPD Task Force recommended BIM as essential to a collaborative process because it facilitates rapid design modeling and iteration, integrated review and clash detection, and construction simulation and sequencing (Figure 2).

A 3D-enabled project supply chain has a central source of accurate, up-to-date information. When using appropriate tools, data exchanges are accurate, 3D models are interoperable, and redundant data entry and modeling are eliminated. Before ever breaking ground, the IPD team thoroughly vets the design, thereby reducing requests for information (RFIs) and change orders that cause delays and cost overruns.

Figure 1: In a typical structural steel supply chain, it can take as many as 16 weeks to produce sufficient information to order steel components from the mill for an automotive manufacturing facility.



Ghafari Associates

Figure 2: 3D modeling builds a virtual prototype to expose problems before construction.

Ghafari Associates

IPD, BIM, and supply chain optimization

Optimizing the supply chain

Designing the optimal project supply chain for a large, multidisciplinary team is challenging, but by eliminating wasteful activities that consume resources, the team will be more successful in finding a better design solution to meet the owner's goals. When the IPD team is assembled, one of the first tasks is to decide how to organize the team for effective collaboration, what processes they will follow, and in what sequence. An effective planning tool is the process map, which is a visual representation of the flow of information among team members and activities. The objective of process mapping is to define and design the supply chain, but it also provides a tremendous opportunity for team building and project planning.

To map project supply chain processes, key stakeholders — those primarily responsible for the design, its evaluation and acceptance, and construction — must engage in a well-facilitated discussion about how they will approach project planning and design. Ideally, the participants are the people who will actually do the work, so they can address specific design and decision-making processes, data sharing and visualization technologies, and review and evaluation procedures — all while increasing buy-in to the agreed-upon process.

The objective of this exercise is to identify the project goals, inputs, activities, decision points, dependencies, constraints, and uncertainties. This establishes a starting point for subsequent conversations to improve shared understanding of the project plan among all participants. Based on a common understanding, the team can enhance performance, eliminate constraints, and reduce uncertainty. Process optimization is iterative, with each revision producing a project plan that is more specific and less prone to waste.

As project goals and objectives are refined, realistic milestones and necessary deliverables can be identified. Abstract deliverables such as percent completion of "schematic design" and "detailed design" should be avoided. Each deliverable must describe a specific component or system. It must be required to make a decision that completes the component or system and moves the project forward, so that additional design work can be finished without risking rework. The team must also address how deliverables will be produced and shared, including the agreed-upon technology for producing design representations.

Model-based design and detailing provides additional opportunities to reduce uncertainty and risk in the supply chain. A 3D-enabled IPD process makes 3D models the focus of frequent multidiscipline design reviews. A reasonable goal for the modeling effort is to accept design as complete when the model is fully coordinated among disciplines, meets the owner's specifications, is constructible with an efficient use of materials and labor, and is within the target budget.

The direct exchange of 3D data between design and construction teams at the right time and with the appropriate level of detail is essential to maximizing the benefits for the overall project (Emdanat, Kruth, and Landis, 2005). Tools that support the direct flow of information throughout the supply chain not only eliminate redundant modeling and associated errors but also enhance understanding among stakeholders. For example, in the design and construction of automotive manufacturing facilities, direct digital exchange to coordinate detailing work among trades accelerates the steel fabrication process.

IPD prevents team members from reverting to the traditional practice of designing, then estimating costs to see if they are within budget. The integrated process involves estimators and specialty contractors early on, so costs are considered well before design is finalized. This enables stakeholders to review the design in progress for value opportunities. The process ensures the most efficient use of materials and labor, and avoids cost overruns associated with re-ordering materials due to late-stage design modifications.

Nine Principles of Integrated Project Delivery

1) Mutual respect and trust
2) Mutual benefit and reward
3) Collaborative innovation and decision-making
4) Early involvement of key participants
5) Early goal definition
6) Intensified planning
7) Open communication
8) Appropriate technology
9) Organization and leadership

Source: Basic Principles of Integrated Project Delivery (www.ipd-ca.net)

Stakeholder relationships in IPD

According to the IPD Task Force, "Integrated Project Delivery is built on collaboration, which in turn is built on trust. Effectively structured, trust-based collaboration encourages parties to focus on project outcomes rather than their individual goals" (IPD Task Force, 2010). Putting together a team of people who have mutual respect and trust for one another may be easier said than done, given the AEC industry track record for combative relationships and discord.

A traditional approach to project delivery creates a hierarchy with the owner/operator on top. A project manager takes the lead through design handoff when the prime contractor assumes control. Often, someone is appointed to the role of owner's representative as an advocate and overseer. The lines of authority on this traditional organization chart cause tension between parties when roles and responsibilities are in dispute.

In contrast, the IPD approach places all parties on equal footing. On an IPD team, the owner/operator, designers, and builders assume joint control. Roles and responsibilities are laid out in a "relational contract" that differs significantly from transactional contract documents. An example of this integrated form of agreement (IFOA) is the Integrated

Case Study: IPD accelerates design and construction for a California replacement hospital

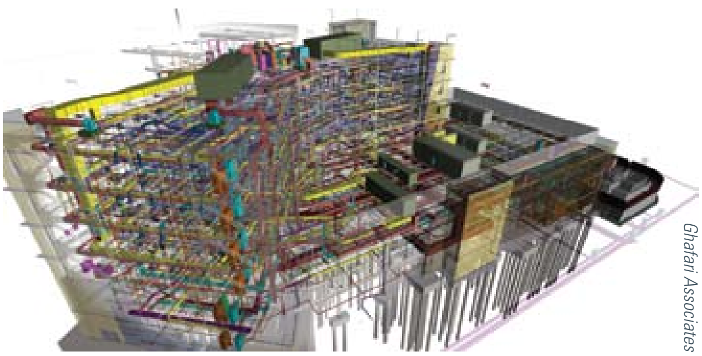
Sutter Health, a Northern California network of hospitals and physicians, is building a next-generation replacement hospital to meet healthcare needs in Castro Valley and surrounding communities. The $320 million project involves construction of a 130-bed, 230,000-square-foot hospital on the Eden Medical Center campus. With construction underway in 2009, Sutter Medical Center-Castro Valley (SMCCV) is on track to open by 2013. The aggressive schedule will deliver the new facility 40 percent faster than comparable projects in California, measured from start of design to completed construction.

The Integrated Project Delivery (IPD) team is comprised of Sutter Health and 10 key team members: The Devenney Group as architect, DPR Construction as general contractor, Ghafari Associates as lean design/virtual construction integrator, TMAD Taylor & Gains as structural engineer, Capital Engineering as mechanical engineer, The Engineering Enterprise as electrical engineer, JW McClenahan as plumbing contractor, Superior Air Handling as mechanical contractor, Morrow Meadows as electrical contractor, and Transbay Fire Protection as fire protection contractor. Together the 11 contract parties formed a "virtual temporary design and construction entity," all with shared financial interest in the project goal — to deliver the facility on time, at or below budget, and with a clinical program configured to transform clinical care (Mauck, Lichtig, Christian, and Darrington, 2009).

Supply chain optimization began in 2007 when the project was just a concept. Ghafari joined Sutter Health and the project team in a workshop to introduce the concepts of process mapping and supply chain efficiencies. In subsequent workshops, the project team applied these concepts to design the project delivery process around lean principles and 3D-enabled workflows.

A key constraint was the Dec. 31, 2008, deadline to submit a complete structural construction document package to the state regulatory agency in order to receive the early permits to start foundation construction. Experience dictated that it would take 15 months to produce the structural submittal. An uncompromising revision of the project plan trimmed wasteful practices from the process, and the team completed the package in less than eight months while also providing the owner with sufficient time to complete the medical program before detailed design activities started.

After the early permit package was submitted, the team's focus shifted to complete the design of the interiors and produce a highly coordinated set of 3D models and design documents with minimal impact on previously issued documentation. Rather than set the goal for this phase to complete the 2D package deliverables, the team set their goal higher to deliver a complete, fully coordinated, and constructable design.


Ghafari Associates

Detailed 3D modeling was required to coordinate systems before fabrication and construction.

One example of this effort is the coordination of all systems and their supports. This is a lengthy process that requires each support location to be identified, often while systems routing is still being coordinated. In many cases, supports are in hard-to-reach locations that require work to occur from expensive lifts or around installed systems. Common practice is to install hangers from below the metal deck after the concrete slab is poured. SMCCV required more than 26,000 hangers, which could be a significant resource-consuming process or an opportunity for improvement.

Early in the design phase, the IPD team set a goal for all mechanical, electrical, and plumbing (MEP) hanger attachments to be inserted from above the metal deck prior to placing rebar and pouring concrete. Subcontractors who had used this technique indicated that it is faster, less expensive, and safer. The team identified the following prerequisites: 1) the design had to be complete and fully coordinated, and 2) all the risks for field rework had to be identified and eliminated. This included coordination of seismic bracing, framing conflicts, and medical equipment supports. To achieve this goal, the team made a significant commitment to plan the design activities and to review the design as it developed collaboratively using the 3D model as the primary tool.

In parallel to design and coordination efforts, the subcontractors explored better ways to layout the supports. They standardized on a technology that allowed them to use 3D model data (x,y,z coordinates) directly from the model and without producing the conventional 2D insert layout drawings. This implementation yielded the following tangible benefits:

- Increased certainty in ceiling coordination, which allowed subcontractors to increase their reliance on offsite fabrication and pre-assembly.
- Elimination of lengthy seismic review processes, since the team color-coded loading criteria for insert loads and made seismic review an integral part of coordination.
- Significant reduction of risk associated with field coordination.
- Realization of 50 percent savings in field labor during the installation of 26,000+ inserts.

To our knowledge, this level of coordination has never been achieved in the industry in association with this project type and schedule constraints. As SMCCV Senior Project Manager Digby Christian told *California Construction* magazine, "The team had to abandon the conventional concepts of designing and planning, and come together as a wide-ranging, multi-company team involving SMCCV, and the designers and builders, and transform the design and construction process." (Newswatch Story, 2009). ▼

Agreement for Lean Project Delivery, which became the basis for the standard IPD form produced by ConsensusDOCS. This model contract was authored by William Lichtig of McDonough Holland & Allen PC, legal counsel to Sutter Health and participant in the hospital's lean project delivery initiative (see "Case Study: IPD accelerated design and construction for a California replacement hospital" on page PDH 5).

The IFOA encourages participants to function as a high-performing collective enterprise. Unlike a design-build agreement that assigns responsibility to one entity for all aspects of project delivery, the IFOA describes the relationships of the IPD team members as well as the principles of lean project delivery (Mauck, Lichtig, Christian, and Darrington, 2009). By signing this agreement, participants accept responsibility for the project as a whole, not just their small parts.

In practice, representatives of the core group — owner/operator, engineer/architect, and general contractor — meet regularly to develop and implement the project plan. As additional members join the team, such as subconsultants and specialty contractors, they sign a joining agreement acknowledging their acceptance of the IFOA terms and lean project delivery principles.

The contract language in an IFOA may include soft targets such as "creative learning environment," "mutual respect and tolerance," and "harmony, collaboration, and cooperation." However, it may also include hard targets such as a "zero RFI goal." In addition, it acknowledges that incentives are integral to optimizing performance, and sharing risks and rewards. The agreement may include provisions that combine design and construction contingencies into one IPD team contingency, or fund incentives with project savings.

Benefits of a lean delivery system

Using a 3D-enabled lean delivery system can help achieve a significant return on investment for all parties. The owner gets a better quality project delivered for the best possible cost in the shortest amount of time. The designers and contractors experience lower risks and improved safety. Critics of IPD complain that it is front-end loaded, with a prolonged design phase that pushes back the construction start date. Advocates point out — and experience demonstrates — that time spent on collaborative design review and iteration actually shortens the construction duration by eliminating laborious RFIs and change orders.

A 3D-enabled approach provides tools for making strategic decisions about project schedule and cost at every point in the supply chain. According to the Construction Industry Institute, 75 percent of construction activities are non-value added, and quality deviations account for up to 12 percent of the total project cost (Mauck, Lichtig, Christian, and Darrington, 2009). IPD exploits the opportunity to add value and achieve quality compliance, surpassing these industry norms.

In Ghafari's experience with General Motors, for example, the direct digital exchange of 3D models between structural engineers and steel fabricators has reduced steel mill order lead time from 10 to 12 weeks to as little as 10 days, measured from the start of the design process. In-model reviews of shop drawing data are significantly faster and less adversarial compared with paper-based exchanges. Digital data sharing also eliminates the generation and handling of thousands of 2D shop drawings.

There is a caveat associated with using sophisticated modeling software. It is the natural inclination of tech-savvy professionals to wield technology for technology's sake — in effect, exploring alternatives, designing variations, and producing deliverables that consume valuable time and resources without supporting decision-making. Lean delivery benefits from BIM only when the deliverables advance the project and/or add value.

Models that are delivered but not maintained quickly become obsolete. Transmitting a 3D model that is 80 percent accurate, for example, is of little value to the steel detailer unless the incorrect 20 percent can be clearly delineated. Likewise, the fabricator must update the detailed models with all design revisions in order for the final models to be of value to the rest of the supply chain partners (Emdanat, Kruth, and Landis, 2005).

Conclusion

Traditional AEC project delivery methods have ingrained practices based on years of operating in an adversarial environment. Changing these practices to incorporate collaboration among equals requires commitment on the part of every team member. The IPD contract establishes the foundation for change. BIM technology provides tools that facilitate change. It is the people who must be willing to embrace new methods for planning and implementing design and construction activities. As one Construction Institute study sagely pointed out: People build projects.

Working together, the integrated project team can avoid the common problems that beset AEC projects and deliver more value with less waste. The actual value delivered will depend on how high they set the bar, and how effectively they retool the project delivery supply chain. Because 3D-enabled project delivery uses the 3D model as a centralized data repository — as a single source of truth for the IPD team — the opportunity for a high-value deliverable at handover is great. Accurate, up-to-date models bring clarity to construction and, when turned over to the owner/operator, inform life cycle management of the asset. ▼

Samir Emdanat is director of Ghafari Associates' consulting group and can be reached at semdanat@ghafari.com. **Robert Mauck, AIA, P.E.**, is vice president of virtual design and construction at Ghafari and can be reached at rmauck@ghafai.com. **Matthew Jogan, AIA**, is a senior consultant at Ghafari and can be reached at mjogan@ghafari.com.

PROFESSIONAL DEVELOPMENT HOURS
Structural Engineering & DESIGN

REFERENCES

- Emdanat, Samir and Christian, Digby, 2010, Integrated Project Delivery Demands New Approaches to Design, **Structural Engineering & Design**, August.
- IPD Definition Task Group, 2007, Integrated Project Delivery – A Working Definition, AIA California Council, June 13.
- Supply Chain Council, 2010, What is Supply Chain?, supply-chain.org, Oct. 13.
- Mauck, Robert; Lichtig, William; Christian, Digby; and Darrington, Joel, 2009, Integrated Project Delivery: Different Outcomes, Different Rules, The 48th Annual Meeting of Invited Attorneys, Victor O. Schinnerer & Company, Inc.
- Emdanat, Samir; Kruth, Lawrence; and Landis, Laird, 2005, Faster, Better, Safer, and Less Expensive Construction: Benefits of Structural Steel Interoperability for the Automotive Supply Chain, AISC Conference Proceedings, American Institute of Steel Construction.
- IPD Task Force, 2010, Basic Principles of Integrated Project Delivery, www.ipd-ca.net, Oct. 14.
- Newswatch Story, 2009, DPR Breaks Ground on Sutter Medical Center, Castro Valley Project, ***California Construction***, July.

IPD, BIM, and supply chain optimization: Bottom-line benefits of 3D-enabled lean delivery for AEC projects

Go to **www.stagnitomedia.com/cedu** to take the following quiz online. Quiz answers will be graded automatically and, if you answer at least 80 percent of the questions correctly, you can immediately download a certificate of completion.

1. Integrated Project Delivery (IPD) is defined as a project delivery approach that integrates:

a) Design and construction

b) 2D and 3D deliverables

c) People and processes

d) Planning and estimating

2. IPD provides an opportunity to create value for the owner/operator by enabling team members to:

a) Collaborate

b) Eliminate waste

c) Optimize workflows

d) All of the above

3. What are the main objectives of process mapping?

a) Supply chain design

b) Team building

c) Project planning

d) all of the above

4. Which of the following is NOT a lean delivery practice?

a) Multidiscipline design reviews

b) Designing then estimating costs

c) Direct digital exchange

d) Efficient use of materials and labor

5. The basic principles that guide IPD stakeholder relationships are:

a) Leadership and performance

b) Authority and responsibility

c) Joint control and tolerance

d) Mutual respect and trust

6. The form of agreement for IPD differs from standard contract documents because it is:

a) Transactional

b) Unenforceable

c) Relational

d) Consensus-based

7. The rewards of an IPD approach for the owner/operator are optimal project:

a) Quality, cost, and time

b) Profit, safety, and risk

c) Value, control, and liability

d) ROI, models, and assets

8. Lean delivery benefits from BIM only when the 3D models that are delivered:

a) Advance the project

b) Add value

c) Support decision-making

d) All of the above

9. When signed by all IPD team members, an integrated form of agreement (IFOA) creates what type of entity?

a) Actual temporary design and construction entity

b) Virtual temporary design and construction entity

c) Virtual permanent design and construction entity

d) Actual permanent design and construction entity

10. A 3D-enabled lean delivery approach can yield measurable project benefits. Which of these results would be realistic to expect?

a) Improved overall project schedule

b) Reduced first cost

c) Improved overall quality

d) All of the above

Intelligent Structural Design

Attend our FREE seminar for PDH credit!

Learn how to significantly increase your productivity with the latest leading structural software.

Join us for a 2 hour seminar highlighting improved workflows for structural engineers!

11/09	Boston, MA
11/10	Calgary, Canada
11/10	Washington, DC
11/11	NY City, NY
11/16	Charlotte, NC
11/17	Pittsburgh, PA
11/18	Atlanta, GA
11/30	San Francisco, CA
12/01	Dallas, TX
12/02	Indianapolis, IN
12/07	Denver, CO
12/08	Seattle, WA
12/09	St. Louis, MO
12/14	Houston, TX
12/14	Chicago, IL
12/15	Costa Mesa, CA
12/16	Baton Rouge, LA
12/16	Minneapolis, MN

Visit us at www.bentley.com/StructuralSeminars2010 to register for a FREE seminar in your area!

Model, Analyze, Design, Document and Deliver… *in an Integrated Workflow*

Having all the applications you need for the tasks at hand, along with the ability to easily synchronize your work with the rest of the project information, helps you get your job done right, fast and profitably. And when the structural project workflow can be integrated, the whole team benefits.

Bentley's new Passport Subscriptions for structural engineers provide access to the full range of structural software, including upgrades, training documents and information that most projects require. These subscriptions are available as an affordable alternative to traditional licensing.

Contact us to learn more.

www.bentley.com/StructuralSeminars2010

Bentley® *Sustaining* Infrastructure