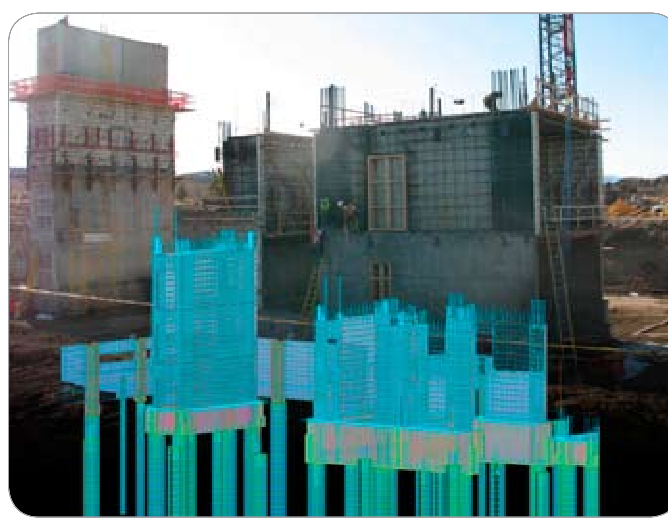
INTERRUPTING THE SUPPLY CHAIN

Enabling Integrated Project Delivery in traditional design and construction projects through innovations in Building Information Modeling

TABLE OF CONTENTS



TEKLA WEITZ BUILD IN GOOD COMPANY. Martino & Luth, Inc. Consulting Structural Engineers AXIS STEEL DETAILING INC. STRUCTURAL CONSULTANTS INCORPORATED

INTERRUPTING THE SUPPLY CHAIN

EXECUTIVE OVERVIEW

> In recent years, the design and construction industry has generated much attention and discussion around two innovations: Integrated Project Delivery (IPD) and Building Information Modeling (BIM). For design and construction professionals alike both topics represent two sides to the same coin. IPD provides the opportunities to alleviate the fractured and contentious nature of information and communication between project stakeholders, while BIM offers the technology to deliver coordinated design and construction information in a new, intelligent, and visual environment.

The rush of attention in and around IPD and BIM has, in many cases, diluted their respective value propositions. Especially in the case of Building Information Modeling, designers and contractors alike have seen the marketplace flooded with competitors that tout the use of internal rendering tools and spatial analysis systems (i.e. clash detection) as value-added services to their clients. While these admittedly are exciting advancement in technologies, they in no way innovate past the standard scope of services included in design documentation and construction responsibilities.

In May 2009 at the AGC BIMForum, **John Moebes** of Crate and Barrel gave a rattling presentation on an Owner's perspective with regard to the return on investment (ROI) associated with BIM. In acknowledging the difficulties of identifying a true value creation processes that building owners can attribute to BIM, Mr. Moebes quite markedly identified where ROI is NOT: "[clash detection] doesn't impress me, it's like trying to get me excited about somebody doing less of a bad job". Mr. Moebes went on to say, "fewer coordination errors, less rework, and fancy renderings…are not positive returns, however, helpful they may be." *

This white paper will review the obstacles inherent in the current delivery methods associated with the design and delivery of structural systems and then further present methods in which both Integrated Project Delivery practices, associated with innovative uses of Building Information Modeling, facilitate a genuine value creation process (from provider to customer – from designer/builder to owner). Leveraging Mr. Moebes insights on "Targets for Positive Return" and the Central Park Tower – Interlocken project team's innovative deployment of Building Information Modeling we will highlight efficiencies gained in:

- **Document production**
- **Estimating and procurement**
- **Placing of work**

These gains will be illustrated in such a manner that benefits are transparent for both those involved with the creation of these optimized processes and those poised to further benefit from a high quality building product itself.

* Moebes, John, "Return on Investment for Building Information Modeling – What One Cranky Owner Would Like to See" 2009, May AGC BIMForum – Dallas, TX http://forum.bimforum.org/downloads/Dallas/Return_On_Investment_for_Building_Information_Modeling.pdf

VISION OF INNOVATION

> In a discussion with **Chris Allen** and **Bruce Cousins**, AIA, Managers of Virtual Design and Construction (VDC) & Operational Excellence, at The Weitz Company, the deployment and use of VDC and Building Information Modeling is part of a corporate driven strategy of process innovation. This strategy is built upon: owner-driven value creation, the minimization of waste, and effective cost/schedule control using lean project management in combination with BIM technology.

Weitz initially committed to company-wide use of VDC/BIM in June 2007. Their initial implementation activities represented the standard use cases for BIM in construction, including coordination between the steel and mechanical sub-contractor's existing 3D models for conflict detection. Early attempts to springboard past design coordination, in the 3D environment, revealed a variety of constraints, (-.e.g. late arriving information, inconsistency between models and drawing integrity, as well as, the duplication of work between 3D and 2D environments.) These early efforts led the Weitz VDC–BIM team to difficult decisions such as, abandoning various design and construction models and reverting back to traditional means and methods to continue work. As Allen states, "initially the technology was deployed without an inherent process understanding".

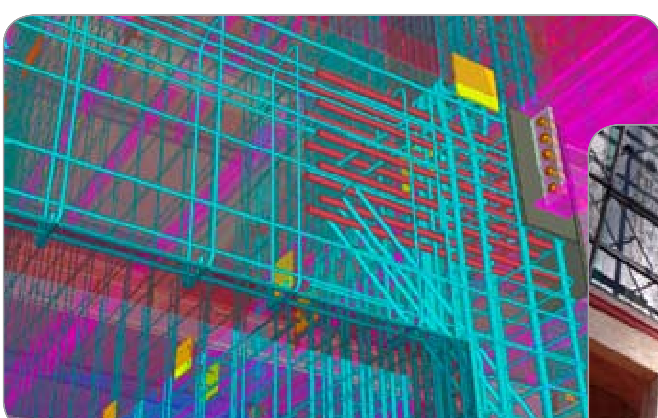
In an effort to align their deployment of VDC-BIM with actual construction process, Weitz further identified opportunities that would yield greater benefits than the standard use cases for BIM in construction. This investigation led them to examine several areas that would yield immediate tangible benefits to both new and existing projects. The primary criteria for these were reducing both cost and risk in operations, optimizing schedule, all without compromising quality.

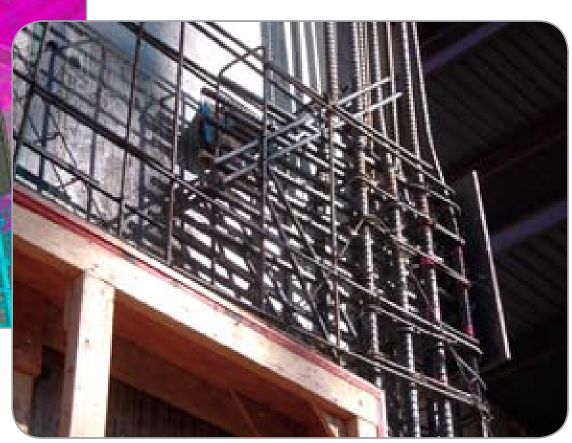
INTERRUPTING THE SUPPLY CHAIN

> Weitz has described their efforts in redefining their traditional design-to-construction coordination and buyout to supplier and specialty subcontractors as "interrupting the supply chain." This terminology helped to establish that these new methods were to be far from business as usual, establishing an innovative culture of stakeholders within the buyout process. It is important to emphasize that this process is not limited to a simple change in the brokering of construction materials, rather, it is the rearranging (and sometimes creation) of relationships to benefit the integrated project delivery process. As with any IPD approach, early involvement of the construction team in the design phase is essential for project success. Driving this early involvement with BIM-enabled team members; improves critical aspects of design and construction, enhancing:

- **Scope clarity**
- **Quantity take-off and estimation accuracy**
- **Identification of constructability constraints**

Beyond simply establishing a corporate vision, Weitz seized the opportunity at Central Park Tower – Interlocken to streamline the delivery of the entire structural system and maximize the use of data and deliverables that could be extracted out of fully coordinated building information models. Doing this paved the way for Weitz to effectively mitigate the risk associated with the structure by ensuring design-to-construction coordination, maximizing off-site fabrication, and facilitating ahead-of-schedule performance of the trades on site.





CAST-IN-PLACE CONCRETE

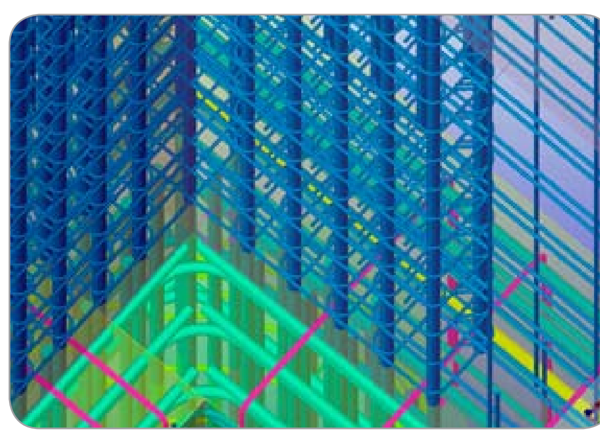
> For self-performing general contractors for cast-in-place concrete (CIP), opportunities to streamline the delivery process carry a high incentive, both externally and internally. The VDC group at Weitz began mapping the processes of their very own self performance field crews. This resulted in a template of construction-driven process requirements that would ultimately define their BIM & VDC implementation. Specifically, two new objectives surfaced:

- **The creation of coordinated and "intelligent" lift drawings ****
- **Engage Professional Engineers (PE) to work hand in hand with the building design professionals of record for constructability and coordination purposes**

The initial budgeted amount of bar was 459, compared to the actual tonnage of 358 tons (a 22% reduction in raw material needed) shipped to site.

These two new objectives widened Weitz's perspective in evaluating the entirety of the existing CIP supply chain, beyond the work of their internal concrete crews. Specifically, the coordination of both embedded items and reinforcing steel in cast-in-place concrete were also identified as critical factors in timely performance of the placement of the concrete system. In standard construction projects, the number of embedded items in concrete pours total thousands, while the number of reinforcing steel members is on the order of tens of thousands. The accurate placement and coordination of embeds and reinforcement is critical to other structural and building services systems that depend on them for support or space reservation. The high costs associated with "corrective" field work when placed incorrectly only amplify the need to accurately coordinate these elements.

In these process refinement discussions at Weitz, it was revealed that a critical portion of the planning and constructability analysis by the self performance crews were already model-based. These were physical, full scale 2D, paper models created by **Davey Holmes** (a Weitz' project superintendent responsible for "vertical" cast-in-place concrete work). Davey's paper model system helped to understand geometric and construction constraints "hidden" in various building designs. Albeit effective, these Davey Information Models or DIMs (as affectionately termed by the VDC team) represent the critical need for a visual based communication method of design and construction intent.



** Drawings made for individual concrete pours intended to aid field crews with: pour dimensions, concrete mix and volumes, placing equipment requirements, formwork considerations, finishing work, and location/quantity of the required embed, conduit and reinforcement material.

STRUCTURAL AND EMBEDDED STEEL

> In addition, Weitz has offered its clients supply chain management services for several years. Services that have been used to purchase finish, fixture, and exterior (FF&E) packages and other long lead time items. Recently these services have expanded to yield benefits in the buyout of structural steel packages. Controlling the structural steel supply chain allows Weitz to secure commitments on both price and schedule of this critical project system. Actively streamlining the steel package delivery resulted in efficiency gains, waste and duplication of effort reduction, rework and schedule compression. These gains were realized across the shop drawing and review process, as well as, the fabrication, delivery, and installation.

Expanding the benefits and knowledge gained in the structural steel package, Weitz began to examine other project systems that could benefit from this BIM-enabled optimized supply chain. A natural next step proved to be the interface between the structural steel and concrete systems. Specifically the steel embeds used to connect the steel members and exterior panels to the concrete frame or cores.

By having the embed plates modeled by the IPD Engineer, Weitz was able to realize many of the same benefits that were discovered in optimizing the structural steel package. Combining the embedded and reinforcing steel into a coordination model Weitz realized:

- **Their self-perform concrete crews could also rely on the BIM to provide accurate information for installation of the embeds and other elements that had previously disrupted schedule in the day to day work they performed.**
- **Their team could further revise the traditional approach to purchasing and supplying concrete reinforcing steel.**

Figure 1:

TRADITIONAL STRUCTURAL SUBCONTRACTOR PROJECT RELATIONSHIP

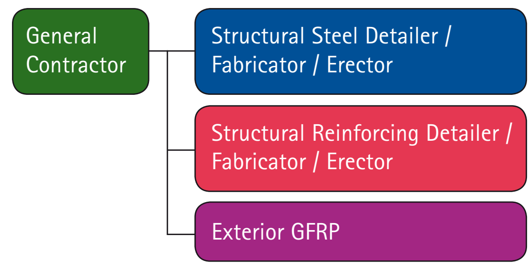
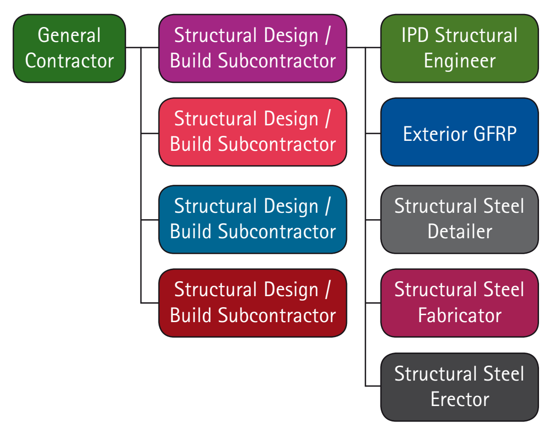


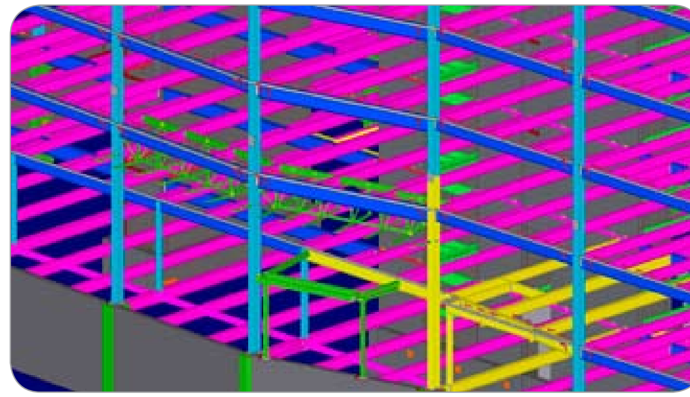
Figure 2:

STRUCTURAL DESIGN-BUILD RELATIONSHIPS INCLUDING IPD STRUCTURAL ENGINEER



MOVING MODELS FROM DESIGN TO CONSTRUCTION

> SCI was hired by Weitz to provide the design, drawings and modeling for both the structural and miscellaneous steel package and the exterior skin. This scope was more than "design interpretation and constructability review". Figures 1 and 2 illustrate the inclusion of an IPD Structural Engineer and Structural Design/Build Subcontractor. From a social standpoint, these team members were created to assist Weitz in bridging the critical gaps between the Architect and Engineer of record and the fabrication/ construction teams. The benefits realized for this project would not have been as great had SCI been restricted to only interpretation and constructability review. Their calculations and drawing packages were submitted to the Structural Engineer of Record as a shop drawing submittal for review and approval (similar to the way precasters provide their systems). Their work was developed at the same time the design team of record was completing the construction documents, and SCI with Weitz participated at all of the design meetings as an integrated part of the delivery team.



Functionally, the IPD Structural Engineer also serves to spearhead the model-based workflows. In this project, SCI served as the IPD Structural Engineer and provided the structural model to Martino & Luth, Inc. to continue a detailed steel reinforced concrete model and Axis Steel Detailing to continue a structural steel fabrication model.

Without model information coming from the architect or engineer of record, SCI created a base structural model. This model then served as a central hub, to which Martino & Luth would further refine with detailed 3D concrete reinforcing steel objects, based on the original EOR requirements and Weitz concrete trade crews. In addition, SCI would further collaborate with Axis, regularly exchanging models back and forth, further enriching the master construction model with detailed connection and production data. Gathered in the master construction model were coordinated MEP system models, subcontractor structural steel models, exterior panel connections, concrete reinforcement and embeds, and construction methods shared by concrete foremen.

With all this data gathered, SCI further expanded their services at Central Park Tower. Housing a complete and accurate concrete system in their BIM, supplemented with the process and constructability knowledge from their collaboration with Weitz's concrete crews, SCI was free to extract the concrete lift drawings. These drawings centralized the necessary material lists, details, and locations of items necessary to coordinate concrete daily work packages.

This expansion of services continued with the building exterior. Three prior buildings at the Interlocken development have precast skins which all were in the budget for those buildings. When a precast skin was priced for the Central Tower project, the exterior skin cost was a major contributor to the original over-budget project estimate. It was decided to investigate an alternate skin which would emulate the precast skin of the previous buildings and better fall within budget. The decision to use the GFRP panels along with having SCI responsible for the design, detailing and modeling (again delivering calculations and drawings which were submitted to the Structural Engineer of Record as a shop drawing submittal for review and approval) was made by Weitz in order to control the exterior systems delivery and meet original cost targets.

Using the coordinated master structural model a glass fiber reinforced polymer panel (GFRP) alternative system was explored. Extracting quantities, precise panel placement locations, developing virtual mock-ups for leaking/wind constraints, and confidently locating the interfaces necessary to ensure proper fit-up, the BIM helped identify a cost-effective and constructible alternative to a previously proven over-budget exterior system. Critical coordination between the exterior skin and the edge of the concrete slab, as well as, the communication of location data to field equipment all helped to ensure seamless fit-up and a continuous flowing schedule.

REAL RETURN

> Adhering to Mr. Mobles "targets for return" in identifying efficiency gains (with respect to: document production, estimating and procurement, placing of work) one can begin to identify incentives for BIM-enabled IPD and its underlying workflow. These incentives come from an understanding of both the intangible and tangible returns that can genuinely be attributed to process and technology innovations.

Certainty is one such "intangible". By centralizing structural project information into a master building information model Weitz ultimately was able to:

- **Test complete final installation**
- **Conform design information to fabrication and installation tolerances and level of detail**
- **Single-source multiple deliverables (e.g. construction documents, fabrication drawings, CNC machine data, material schedules, and performance/work drawings/Lift Drawings**
- **Align material delivery with daily crew work packages to eliminate both on-site excess inventory and underutilized truck loads.**

"I propose that certainty is equal to quality", says Allen, "and all this combined equals the cost savings that we experienced".

In tangible dollars, one does need to look much farther than how this certainty translated in material savings for the rebar supply chain. By providing the rebar manufacturer with detailed reinforcement information from the BIM, Weitz created a unit price purchase agreement with the manufacturer. When compared to the initial standard lump sum bids for rebar (which normally includes vendor markups due to uncertainty in quantity and type of bar), the project experienced an initial **rebar material buyout savings of $25,986**.

Due to the need to move forward with estimated quantities Weitz coupled the unit price purchase agreement for the bar with a "budgeted" tonnage of bar, from the original lump sum estimates. The initial budgeted amount of bar was 459, compared to the actual tonnage of 358 tons (a **22% reduction in raw material needed**) shipped to site. Further, with such predictable coordinated fabrication, the project realized a waste reduction of rebar to less than one-tenth of one percent for the project.

When combining the net effect of the initial buyout cost savings with the 22% material savings, Weitz generated a **total project savings of over $113,000 for rebar** on Central Park Tower. The total reduction in fabrication and detail costs from this unit price procurement structure amounted to **a total of 8.2% savings** (when evaluating the per ton lump sum prices to the per ton unit price totals).

Quantifying the impact of problems that are resolved is always a difficult task to do. How do you determine the cost of something that never happened? In the case of Central Park Tower, Weitz used a control project to benchmark coordination performance. When compared to a similar CIP core structure using tradition design and delivery the costs associated with RFI and their ultimate impact to what the owner would be assessed in addition to the agreed GMP is made apparent. See Figure 3.

Figure 3:

BENCHMARK COMPARISON OF CENTRAL PARK TOWER COORDINATION PROCESS

WEITZ SIMILAR COMPARISON PROJECT
April 2008
9 stories
CIP core
On schedule
44 RFIs for CIP core walls
14.7% of total RFI's on project
Range of costs for RFIs (includes direct and indirect project costs:
$97,549 – $161,549

CENTRAL PARK TOWER
April 2009
11 stories
CIP core
Two weeks ahead of schedule
0 RFIs for CIP core walls

Combining the $25,986 savings on the rebar supply bid, the $78,320 actual quantity vs budget savings, and the range of $97,549-$161,549 in savings from the coordination costs attributed to similar work in Figure 4, **Weitz was able to create a total model-based CIP detail/fabricate/erect process savings of $201,855 – $265,855. This was in addition to the (2) week reduction in construction schedule.**

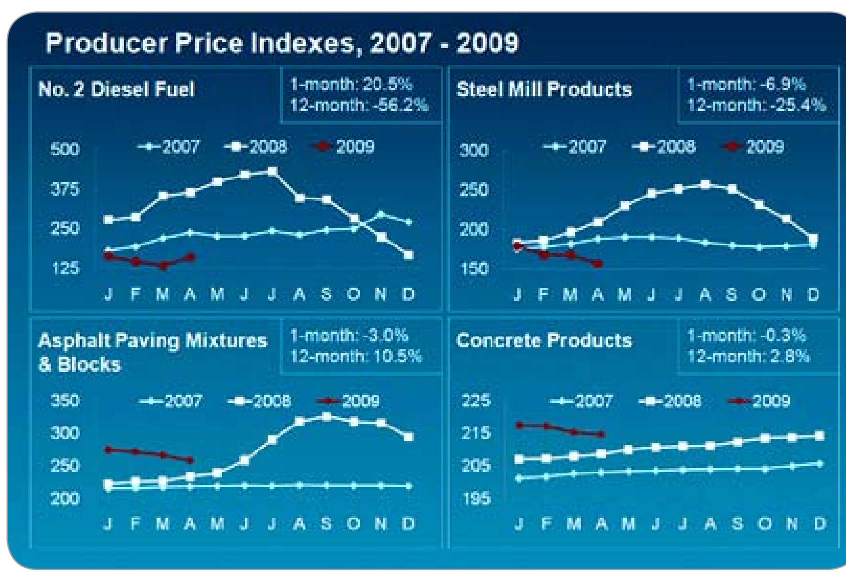
The schedule improvements as a result of this process speak volumes for the effort at Central Park Tower. For the steel package the tight relationship and interactivity between SCI and Axis resulted in a considerable reduction in budgeted detailing hours. Originally Axis budgeted 1,600 manhours based off of the project type. **This estimate was close to 35% over the actual manhour consumed to detail the structural steel package at 1,050 manhours.**

The direct CIP and structural steel savings from combining BIM with IPD processes range from $500,855 to $564,855"

Again due to the iterative and concurrent work being performed by SCI and Axis, an early fabrication start date was possible. Because of the completeness of construction documents (due to early detailer and fabrication input), **the fabrication start following CDs was reduced by 56% to 5 weeks. This translated to a reduction in initial steel delivery time by 50%** or 8 weeks following CDs.

The net effect of comprehensive construction/fabrication information early in the design process reaped a host of other project rewards. A normally tedious approval process was reduced to few design team comments and ultimately a very light and efficient structural system at 8.6 pounds/square foot. The previously combine 35% costs **savings in detailing costs can be coupled with a $250,000 in mill order savings to the owner** as a result of certainty that came with early accuracy. In regards to direct coordination costs, the steel package resulted in only two RFIs with zero change orders in additional field costs. **These savings total a $299,000 reduction in direct costs for the structural steel package.**

Figure 4:



"Source: Kenneth Simmonson – Chief Economist, Association of General Contractors"

CONCLUSIONS

> An ever-present market dynamic of material price volatility is incentive enough to apply supply chain management principles in the construction industry. A recent report from the Chief Economist of the AGC on pricing indexes in construction showed a variation of approximately 75 points, over a 12 month period in 2008, when compared to steel prices at EOY 2003. Variance such as these inevitably can cause dramatic shifts in project budgets over time. The certainty and accuracy built-in to the processes applied at Central Park Tower minimized the impact of such variances impacting its project costs.

The process at Central Park Tower ultimately unfolded into what would be a hybrid implementation of IPD, in an otherwise contractually standard building project. It is important to note that the contractual arrangements established at the onset for the Central Park Tower is based upon a standard Guaranteed Maximum Price (GMP), void of creating incentive for a value creating collaboration amongst its stakeholders. Despite this constraint, the project team effectively demonstrated that the coupling of BIM and IPD workflows can drive real return to project participants, as well as, building owners.

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