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WORK STRUCTURING AT THE BOUNDARY OF REALIZATION: A CASE STUDY ANALYSIS

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ABSTRACT

Work structuring as a method of managing handoffs has been extensively investigated as it applies to supply chains within a project. Work structuring techniques help teams manage the supply chain and improve project delivery. Existing case study research, however, tends to focus on particular silos within a project, such as curtain wall or doors, frames, and hardware. The authors hypothesize that work structuring techniques can also be effectively applied at a project-scale to improve overall project delivery. In every project, there is Boundary of Realization, or transition from completion of design intent to "make ready" for construction. This Boundary of Realization period is characterized by a multitude of formal informational hand-offs between design and construction stakeholders, dictated by contract obligations and ingrained behaviours. The authors use case studies to examine the implementation of work structuring techniques at a project scale, the set-up of contractual requirements, and the patterns and methods of communication. With an understanding of contractual relationships and work structuring techniques used to manage a project's informational supply chain, the authors diagram methods for structuring informational hand-offs at the Boundary of Realization.

KEYWORDS

Boundary of Realization, Work Structuring, Work Chunk, Production Unit, Hand-off.

LITERATURE REVIEW

It is important to situate the discussion in the context and vocabulary of current research. Christian, et al (2014) provide a four phase project delivery framework based on the "V" model. The first two phases, Value Definition and Representation of Solutions, are separated from the last two phases, Realization of the Solution and Value Capture, by the Boundary of Realization (BOR). The BOR is point at which the project moves from representation to realization, and is the "point at which the quantity and rate of resource consumption typically accelerates by the greatest margin" (Christian et al 2014).

Christian et al (2015) define the ideal state of the realization phase to have "zero risk of failure because the representation was perfect and was analyzed to confirm with

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certainty that the value defined was intact and that the constructability was flawless." The BoR shown in the ideal state is a single moment.

Figure 1: Four Phase Project Delivery from Christian et al 2014

Work structuring is the process of analysing project supply chains and defining the work required to bring value to the customer; or simply put it "determines what work must be done on a project, who would be best-suited to execute it, and when they should be doing it." (Tsao 2005) Work Structuring consists of three basic components:

- **Production Unit:** The direct production of workers that share responsibility for similar work (Ballard 2004).
- **Work Chunk:** The unit of work that is handed off from one production unit to the next (Tsao 2005).
- **Hand-off:** The combination of (a) completion, (b) release and (c) acceptance of a work chunk between production units (Tsao 2005).

In her 2005 thesis, Tsao researches a framework for studying the concept of work structuring through in-depth analysis of case studies with the following findings.

Table 1: Tsao Work Structuring Cross Case Study Findings

Cross-Case Similarities	Cross-Case Differences
• Product design often defines 'means and methods' • Moving work upstream improves project delivery • Contracts impact feasibility of system-level thinking • A broader view can reveal high-impact changes • Tolerance management is a work structuring objective • Received traditions prevent innovation in work structuring • Successful projects still have room for improvement	• Product supply approach impacts degree of integration • Owner type influences degree of integration • Push for integration can come from any project participant

To understand how project teams create project-specific work structures, a baseline understanding of industry standard contract language is needed. The American Institute of Architects (AIA) provides that standard, having published sample contracts since 1911 with decennial updates. Series A of the AIA contracts represents the owner/contractor agreements and series B represents the owner/architect agreements. A study of the language describing hand offs between design and construction stakeholders in the most the prevalent AIA documents, A201 and B101, is summarized in Table 2 (AIA 2016)

Table 2: Study of AIA Language regarding Handoffs at the BOR

Handoff	A201-2007 (General Conditions of the Contract for Construction)	B101-2007 (Standard Form of Agreement: Owner and Architect)
Contract Documents	• The Contract Documents shall not be construed to create a contractual relationship of any kind between the Contractor and the Architect or the Architect's consultants, Subcontractor, or between any persons or entities other than the Owner and the Contractor. • The Architect will provide administration as described in the Contract Documents	• The Architect shall provide administration of the Contract between the Owner and the Contractor as set forth in AIA A201–2007, • Architect shall not have control over or responsibility for construction means, methods • Drawing deliverables defined - Prelim Design, Schematic Design, Design Development, Construction Documents
Submittals	• Shop Drawings are drawings, diagrams, schedules and other data specially prepared • Shop Drawings, Product Data, Samples and similar submittals are not Contract Documents. Their purpose is to demonstrate the way by which the Contractor proposes to conform to the information given and the design concept .. • The Contractor shall perform no portion of the Work for which the Contract Documents require submittal and review of Shop Drawings, Product Data, Samples or similar submittals until the respective submittal has been approved.	• "The Owner and Architect acknowledge that in order to construct the Work the Contractor will provide additional information, including Shop Drawings, Product Data, Samples.. • "The Architect shall review and approve or take other appropriate action upon the Contractor's submittals such as Shop Drawings, Product Data and Samples, but only for the limited purpose of checking for conformance with information given and the design concept expressed in the Contract Documents.
RFIs	• The Contractor shall promptly report to the Architect any errors, inconsistencies or omissions discovered by or made known to the Contractor as a request for information in such form as the Architect may require. • The Architect will review and respond to RFIs about the Contract Documents.	• RFIs shall include, at a minimum, a detailed written statement that indicates the specific Drawings or Specifications in need of clarification and the nature of the clarification requested. The Architect's response to such requests shall be made in writing within any time limits agreed upon.

INTRODUCTION

The Boundary of Realization is described as the moment that "drawings of stone blocks become the stone blocks themselves" (Christian et al. 2014). Two important implications of this statement must be examined.

First, it becomes apparent that the Boundary of Realization is indicative of a shift of control in the project. In the representation phase, the architect is responsible for nurturing and developing the design intent; once the vision becomes real, or the "stone blocks themselves", the contractor has become responsible for the execution of the design intent. In traditional contracting, the architect and contractor are not contractually linked. The result is that the progression and hand off of the project vision happens between two parties with no direct relationship and differing contractual motivations.

Second, is should be recognized that the project does not cross the Boundary of Realization as a unit, but in phases. Early work, such as structure, is released and installed before design is complete on later work such as finishes. During the project-wide transition over the the BOR, coordination of building details is a negotiation between scope that has materialized, and scope that is still in the representation phase.

The hand off process between contractor and architect in the traditional Guaranteed Maximum Price (GMP) contract is largely prescriptive[3]. Upon receipt of contract drawings, the contractor shall complete submittals to demonstrate compliance with design intent, and submit RFIs to clarify the drawings. In this way the project moves, scope by scope, past the Boundary of Realization. To comply with a prescriptive contract, a party merely needs to comply with the outlined processes. Collaboration for the purpose of bringing additional value to the owner is not incentivized.

As lean construction has gained popularity, the AIA published the *C195–2008 - Standard Form Single Purpose Entity Agreement for Integrated Project Delivery (IPD)* (AIA 2016). By tying all major participants to on contract with shared risk and reward, IPD defines the relationships between project stakeholders while avoiding prescriptive means and methods. Figure 2 contrasts the bifurcated contact structure of GMP with collective structure of IPD.

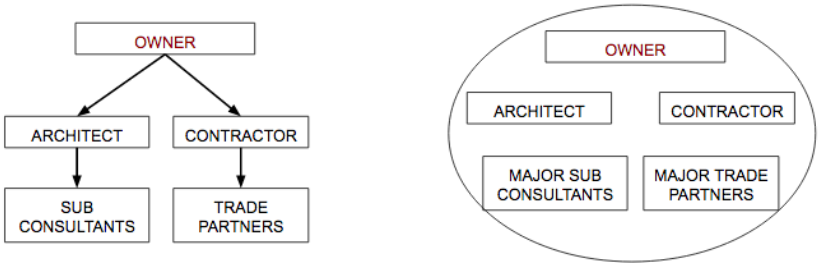

Figure 2: Relationship Structure for GMP (left) vs. IPD (right) Contract Delivery Type

CASE STUDIES

Five projects were identified whose project teams were actively analysing and questioning traditional hand offs. All projects were new vertical construction, with a value greater than 50MM USD. The methodology employed involved surveying project teams via a cloud-based worksheet including process questions and relationship diagrams, interviews with

[3] Throughout this paper, the term "prescriptive" is used to describe contractual requirements that include specific steps to reach a desired outcome. The term "perfomative" is used to describe contractual requirements that define the desired outcome, but not the specific steps.

key contacts from general contractors and design teams, and verification of findings via cloud collaboration. No owners participated in the in direct interviews. Follow up research to validate the benefits of the research findings to the owner would be beneficial. During the interview process, three topics were discussed.

- The Project's formal contractual relationship and how it differed from the self-described relationships
- Informal communication channels which occur outside contract requirements
- The handoffs and processes at the Boundary of Realization: Drawings, Specifications, RFIs, and Shop Drawings

Teams were asked to describe their relationships and processes in detail, and process deviations from AIA contracts were analysed through work structuring process mapping. Table 3 presents the communication findings. "Formal" indicates the team followed contractual guidelines; "Informal" indicates that there was communication outside of the contractual guidelines; and "Open" indicates that the team co-located in a Big Room environment.

Table 3: Case Study Contracts and Communication

	Contracts		Communication				
Case Study	**Actual**	**Self Describe**	**Owner / Architect**	**Owner /GC**	**Architect / GC**	**Sub Trade / Engineer**	**GC Self Perform Scopes**
CS-1	GMP	GMP	Formal	Formal	Informal	Informal	Limited
CS-2	GMP	"IPDish"	Formal	Informal	Informal	Informal	Structure, Framing
CS-3	GMP	"IPDish"	Open	Informal	Informal	Informal	Structure, Framing
CS-4	IPD	IPD	Open	Open	Open	Open	Concrete, Interiors
CS-5	IPD	IPD	Open	Open	Open	Open	Limited

SPECIFICATIONS AND SUBMITTALS

Specifications are developed as a written description of project requirements not shown in the drawings. Among other things, they outline product data, and what is required for submittal by the contractor. The purpose of Submittals is, according to the AIA, to "demonstrate the way by which the Contractor proposes to conform to the information given and the design concept expressed" (AIA 2016).

All case study teams modified the specifications to align with construction execution. CS-1 had its design-assist MEP trade partners review and mark up the specification to conform with their negotiated scope of work. CS-4 developed a mostly prescriptive specification, but invited the general contractor and trade partners to comment and provide substitution requests prior to the final submission of the Specifications to the state review agency.

CS-2 and CS-3 placed emphasis on the performative specification over the prescriptive specification. For example, when specifying concrete, the specifications would provide

performance requirements (3,000 PSI strength) rather than prescriptive requirements (specific mix design). The contractor in CS-3 went so far as to provide the architect with specific language for inclusion in the specifications.

CS-5 questioned the need for specifications at all. Acknowledging the conventional construction wisdom that "no one reads the specs, anyway", they asked the IPD stakeholders which parts of the specifications were important:

- Architect: To define product data and establish QA/QC requirements
- Structural Engineer: To include "or approved equal" language
- Mechanical Engineer: To determine which equipment to buy
- Contractor: To force trade partners to submit required submittals
- Owner: To define requirements for record handover to operations and closeout

After realizing the true value of the specifications to the project, the team was able to reduce the size of the specifications by approximately three quarters.

A major finding in the case studies, mapped in Figure 3, is the separation of performative and prescriptive elements of the specifications. By identifying the material on the project that only has performative requirements and soliciting input from suppliers, the project team can reduce variablity in lead times and cost. The teams have restructured the work package "create specification" into two smaller packages – performative and prescriptive, and then assigned the work to the entity with the most incentive for creating project value. In this way, teams avoid having the designers inadvertantly determining means and methods, and reduce outcome variability.

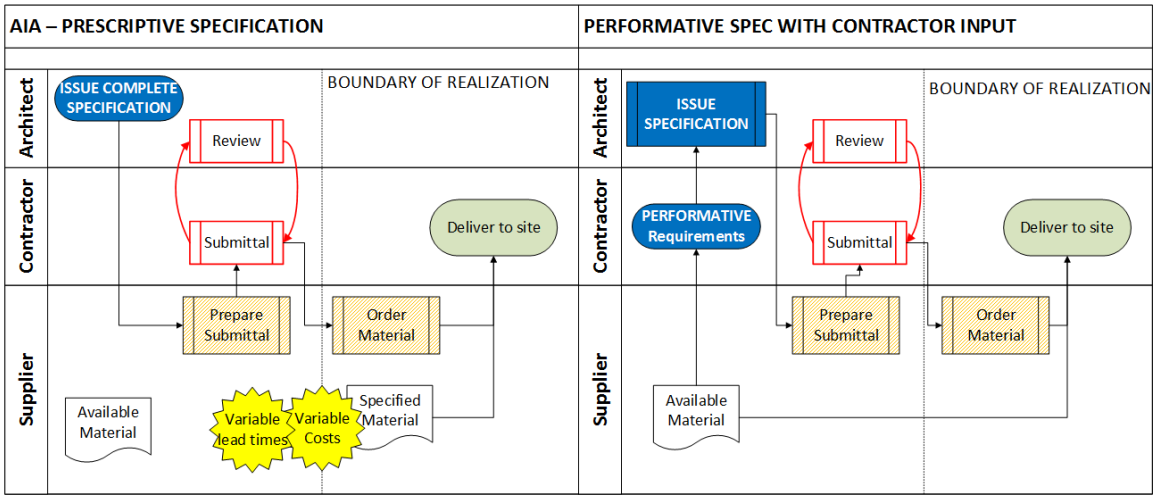

Figure 3: Specification - Submittal Process Map: Traditional (L) vs. Restructured (R)

DRAWINGS AND REQUESTS FOR INFORMATION (RFIS)

The modifications to the process of drawing issuance and RFI response are sufficiently unique as to warrant individual summary.

CS-1, the most self-described traditional project, adhered to the drawing issuance model described by the AIA contracts. Periodic sets of drawings were issued, and prior to

construction, contractor constructability input was solicited. Post bid, periodic bulletins were issued to capture design changes, owner requests, and RFI clarifications. To mitigate RFIs, the team kept a log of design issues and maintained a policy of only submitting confirming RFIs. Basically, whether through the logs or direct communication, the issue at hand was thoroughly understood by all parties prior to submission. To this end, the RFI acted only to document the change that affects code, aesthetics, or performance of the building. By separating the solving of the issue from the documentation of the solution, the team reduced the variability of outcome of the work hand off.

CS-2 radically changed the pace of drawing issuance. Throughout the realization phase, informal progress sets of drawing were issued and processed on a weekly basis according to the following cycle:

- **Friday:** Drawing of new work issued by design team.
- **Monday:** Historical Drawing Overlays sent to affected trades for pricing.
- **Tuesday:** Rough order of magnitude pricing due to contractor by end of day.
- **Thursday:** Pricing meeting with owner to review and release new work.

Official sets of drawings were produced and submitted to the Authorities Having Jurisdiction (AHJ) on a monthly basis. RFIs were only submitted if a substantial change needed to be executed prior to the official drawing issuance. If an RFI was issued, it was a full sheet RFI. It should be noted that this cycle lasted well into construction, and occasionally required the removal of installed work. While this seems like waste, the owner on this project valued the ability to modify the design over the cost of modifying installed work, and therefore, this process did deliver maximum value to the owner.

The contractor in CS-3 was able to avoid many potential RFIs by moving the constructability review upstream. The contractor relied heavily on building information modelling (BIM) to develop field work packages that used model-based layout in lieu of 2D contract documents. When issues arose during creation of the work package, the team started a "BIM Con", or tracking log. When creating work packages for a scope, the BIM con responses were included.

CS-4 worked closely with the state review agency to structure the approval process using a combination of confirming RFIs that were captured periodically into a full sheet drawing change order. The Boundary of Realization on this project was almost exclusively controlled by the AHJ and their on-site inspector of record.

CS-5 also issued drawings on a weekly basis. Due to the specific jurisdiction, it was possible to capture changes retroactively through the as-built process, making RFI approval by the AHJ unnecessary. In fact, CS-5 did not use formal RFIs at all on the project. If a large issue arose, the project would hold a "swarm", or gathering of all entities needed to resolve the issue. The issue was discussed, a plan was formed, and the solution was represented in the next drawing issuance. This 'no-RFI' policy extended to sub trades that were outside of the IPD risk pool. All companies were required to complete an on-boarding process to introduce them to lean philosophy prior to construction start.

The drawing-RFI process is shown in Figure 4. The Process Map on the left shows the process as described by the AIA; characterized by inconsistently batched releases of information. The information needed to build is contained in ***both*** project drawings and individual RFIs. The Process Map on the right shows the restructured work packages. By issuing and reviewing drawings every week, the team have eliminated RFIs. Additional benefits gained are reducing the variability of drawing updates to the field and the collection of all information needed to build into ***one*** document.

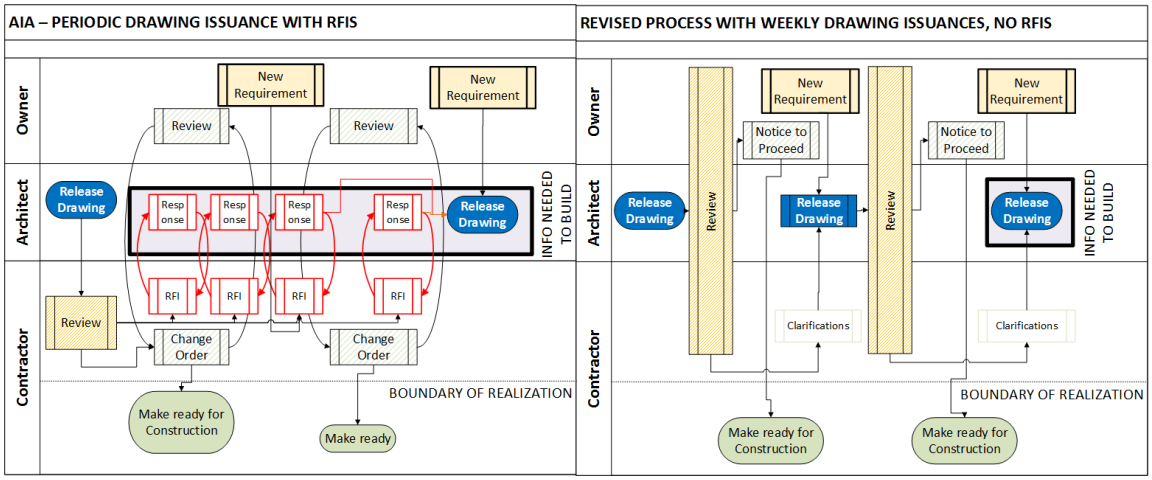

Figure 4: Drawing - RFI Process Map: Traditional (L) Vs Restructured (R)

DISCUSSION

To structure the discussion, the authors reference the cross project findings in Tsao's 2005 thesis and discusses the conclusions which the case study research supports.

Product design often defines 'means and methods'.

The specification and submittal workflow, as described by the AIA, tasks the architect with complete performative and prescriptive descriptions of project components. Recognizing that the architect's primary contractual motivation is to produce code-compliant drawings, the contractor in CS-2 provided the balance of information related to constructability. Multiple case studies had contractors providing significant input into specification and drawing creation.

Moving work upstream improves project delivery.

In changing the specifications of the project to align more closely with the needs of the respective customer, the teams are influencing the supply chain of information on their project. By having the parties involved with construction execution provide input into the specifications, the teams avoid inadvertently having the design team set the means and methods for construction. As a result of the performative specifications, CS-2 and CS-3 indicated that the response time on specifications was reduced. The teams effectively reduced the size of the work package to be reviewed to that which was necessary for performance. The team divided the work package and aligned the work with the entity who most benefited by correct execution

Contracts impact feasibility of systems level thinking.

The case study finding demonstrated that IPD contracts allow for more comprehensive revisions earlier than with GMP contracts. CS-5 modified the submittal review process to eliminate waste. The steel supplier modelled and detailed the steel in three dimensions. Rather than abstracting the information into a two dimensional submittal, the team reviewed and commented on the shop drawings from within the native authoring program. However, CS-2 and CS-3 demonstrated that despite formal contract requirements, the contractor was able to use informal communication through relationship management to significantly alter work structures.

Received traditions prevent innovation in work structuring.

The RFI process was originally put in place by the AIA to allow the architect to issue a simple drawing clarification, however, this process leads to dispersed information. Clarifications through BIM collaboration or automated drawing can be less of a burden on the architect than responding to an RFI, as demonstrated by CS-3 and CS-5. The need for RFIs as the specific vehicle for clarification is driven almost exclusively by legacy contract or AHJ requirements, as shown by CS-4. If teams can free themselves from contractual RFIs, they open the possibility a more streamlined single source of truth.

ADDITIONAL FINDINGS

Contractors who self-perform take more responsibly for the project supply chain

The team on CS-3 expanded the idea of a shop drawing as conformance to design intent and created "work package drawings" based on the coordinated model. In the field, work packages are used in lieu of construction documents. In traditional contracting this would be perceived as taking on more risk. CS-3 realizes that the greatest risk is not completing the scope correctly. CS-3 added an additional hand off in the shop drawing process, but they tailored the hand off to the needs of the customer - the installation crew.

Project supply chains should be restructured to reduce the variability of information released for construction

CS-3 and CS-5 dramatically reduced the size of the drawing issuance work package from several months' worth of work to one week. By issuing full sheet RFIs, CS-3 approached one-piece flow. This restructuring has many benefits, including a reduced cycle time for constructability and cost feedback. RFIs, as clarifications of the contract documents, become nearly obsolete if changes are picked up in a weekly drawing cycle. Eliminating RFIs removes a whole documentation cycle and consequent waste. In this process, the drawings become the single source of truth for construction execution.

CONCLUSION

The case study findings have demonstrated that that work structuring is an appropriate lens through which to study and restructure project scale informational supply chains. By using process maps to study the flow of information in the Boundary of Realization period, it is possible to understand and restructure handoffs to improve project delivery.

The case study findings have demonstrated that collaborative contracts enable complete restructuring of informational supply chains. The research has also demonstrated that with informal collaborative relationships, projects with traditional contracts can also successfully restructure informational supply chains. In both cases, constraints often remain external in the tolerance of the Authority Having Jurisdiction.

The findings of the case studies demonstrate that the teams have restructured their informational supply chains to (1) incorporate constructability input into the contractual documents and (2) structured information flow to reduce variability of information to the field. Projects seeking to streamline handoffs at the Boundary of Realization should consider the concrete case study examples of process improvement, and then map and analyse their process with these principles in mind.

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