IN THIS ISSUE:

Designing a Modular Building: A Case Study for Modular vs. Conventional Design for an Apartment Building

Examining the Microeconomics of Bid Difference of Engineer & Contractor Bids in Highway Construction

Application and Usage of Design-Build by State DOTs

Construction Disputes in the United States and the United Kingdom: A Comparison

Assessment of Electrical Contractors’ Perception and Practices with Project Risk Management
ABOUT THE AIC

Founded in 1971, the American Institute of Constructors mission is to promote individual professionalism and excellence throughout the related fields of construction. AIC supports the individual Constructor throughout their careers by helping to develop the skills, knowledge, professionalism and ethics that further the standing of the construction industry. AIC Members participate in developing, and commit to, the highest standards of practice in managing the projects and relationships that contribute to the successful competition of the construction process. In addition to membership, the AIC certifies individuals through the Constructor Certification Commission. The Associate Constructor (AC) and Certified Professional Constructor (CPC) are internationally recognized certifications in the construction industry. These two certifications give formal recognition of the education and experience that defines a Professional Constructor. For more information about the AIC please visit their website at www.professionalconstructor.org.

OUR MISSION

• To promote individual professionalism and excellence throughout the related fields of construction.

• A qualifying body to serve the individual in construction, the Constructor, who has achieved a recognized level of professional competence;

• Opportunities for the individual constructor to participate in the process of developing quality standards of practice and to exchange ideas;

• Leadership in establishing and maintaining high ethical standards;

• Support for construction education and research;

• Encouragement of equitable and professional relationships between the professional constructor and other entities in the construction process; and

• An environment to enhance the overall standing of the construction profession.

Approximately 10-15 articles are published annually in The American Professional Constructor. To maintain our high standards of publication, AIC requires the support of competent and committed reviewers. We would like to express our deep gratitude to the following reviewers of the articles published in the Journal’s Spring and Fall 2018 Issues:

President
Brian Holley, CPC
VScenario

Secretary
Scott Cuthbertson
PwC

Treasurer
Mark Hall, CPC
Hall Construction

AIC BOARD OF DIRECTORS 2017
National Elected Directors
Joe Burgett (Elected) (2016-2019)
Bradley Monson (Elected) (2017-2020)
Lana Coble (Elected) (2017-2020)
Thad Nicholson (Elected) (2017-2020)
Robert Aniol (Elected) (2017-2020)
Scott Cuthbertson (Elected) (2017-2020)
Eric Vechan (Elected) (2018-2021)
Jason McAnarney (Elected) (2018-2021)
Murray Papendorf (Elected) (2018-2021)
James Hogan (Elected) (2018-2021)
Roger Liska (Chair, Constructor Certification Commission)
Jason Lucas (Chair, Publications Committee)
Wylie Bearup (Chair, Programs & Education Committee)
Austin Beaver (Chair, Corporate Sponsors Program)
Jim Nissen and Murray Papendorf (Chair and Vice-Chair, Membership Committee)
Chris Clifford (Chair, AIC Ethics Commission)
Chris Lewis (AIC State Representative Program)

Vice President
Brad Monson, CPC
Colorado Dept. of Public Health & Environment

Past-President
Greg Carender, CPC
EdgeConneX

Non-Voting Past-President Directors
Greg Carender (Immediate Past President)
Joe Rietman, (Past-President)
Paul Mattingly (Past-President)
David Fleming (Past-President)
Tanya C. Matthews (Past-President)
Andrew Wasiniak (Past-President)
Mark Giorgi (Past-President)
David Mattson (Past-President)
Steve DeSalvo (Past-President)
Jim Redlinger (Past-President)
AIC PAST PRESIDENTS

1971-74 Walter Nashert, Sr., FAIC
1975 Francis R. Dugan, FAIC
1976 William Lathrop, FAIC
1977 James A. Jackson, FAIC
1978 William M. Kuhne, FAIC
1979 E. Grant Hesser, FAIC
1980 Clarke E. Redlinger, FAIC
1981 Robert D. Nabholz, FAIC
1982 Bruce C. Gilbert, FAIC
1983 Ralph. J. Hubert, FAIC
1984 Herbert L. McCaskill Jr., FAIC
1985 Albert L Culberson, FAIC
1986 Richard H. Frantz, FAIC
1987 L.A. (Jack) Kinnaman, FAIC
1988 Robert W. Dorsey, FAIC
1989 T.R. Benning Jr., FAIC
1990 O.L. Pfaffmann, FAIC
1991 David Wahl, FAIC
1992 Richard Kafonek, FAIC
1993 Roger Baldwin, FAIC
1994 Roger Liska, FAIC
1995 Allen Crowley, FAIC
1996 Martin R. Griek, AIC
1997 C.J. Tiesen, AIC
1998-99 Gary Thurston, AIC
2000 William R. Edwards, AIC
2001-02 James C. Redlinger, FAIC
2003-04 Stephen DeSalvo, FAIC
2005-06 David R. Mattson, FAIC
2007-09 Stephen P. Byrne, FAIC, CPC

2009-11 Mark E. Giorgi, FAIC
2011-12 Andrew Wasiniak, FAIC, CPC
2012-13 Tanya Matthews, FAIC, DBIA
2013-14 David Fleming, CPC, DBIA
2014-15 Paul Mattingly, CPC
2015-16 Joe Rietman, CPC
2016-18 Greg Carender, CPC
ARTICLES IN THIS ISSUE

PAGE 6
Designing a Modular Building: A Case Study for Modular vs. Conventional Design for an Apartment Building
Christine Piper and Arun Thodupunoori

PAGE 18
Examining the Microeconomics of Bid Difference of Engineer & Contractor Bids in Highway Construction
Robert Ryan, Randy R. Rapp, Mark Shaurette, and Sarah Hubbard

PAGE 30
Application and Usage of Design-Build by State DOTs
Dennis C. Bausman, Mashrur Chowdhury, Chirstopher Cummings, and Sasi Selvam

PAGE 39
Construction Disputes in the United States and the United Kingdom: A Comparison
Anusree Saseendran, Ben F. Bigelow, Zofia Rybkowski, and Dawn Jourdan

PAGE 47
Assessment of Electrical Contractors’ Perception and Practices with Project Risk Management
Anthony Perrenoud
Designing a Modular Building: A Case Study for Modular vs. Conventional Design for an Apartment Building

Christine Piper, Clemson University | cpiper@clemson.edu
Arun Thodupunoori, Clemson University | athodup@clemson.edu

ABSTRACT
To alleviate the diminishing number of tradespeople in the US construction industry, modular construction is an alternative construction process that could be used for repetitive construction applications. However, there are some misconceptions about modular construction including: limited architectural design options, design restrictions, lower quality, unaffordable and inability to design for sustainability. Modular construction is a process that streamlines the construction process and saves a significant amount of time while delivering a high quality building. In response to the misconception of design options, this case study presents the design considerations for transforming an apartment building that was designed and constructed using conventional methods to one that could be built using the modular construction process.

Keywords: Modular Construction, Modular Design, Apartments, Building, Architecture

Christine Piper, PhD, has completed research in the areas of WBE certification, attracting and retaining craft workers, schedule development, and continuing education programs for National Association of Women in Construction, Modular Building Institute and ITT Tech.

Arun Thodupunoori, MCSM, is a graduate student who performed research under Dr. Piper’s direction in the area of design concepts related to modular construction.
INTRODUCTION

Labor shortage in the United States is impacting the construction industry. According to the Bureau of Labor Statistics data and analysis by National Association of Home Builders, there were 214,000 (about an 80% increase from previous two years) construction sector jobs in the middle of the year 2016 (NAHB 2016) that were not filled. “A 2011 Sage report described Permanent Modular Construction (PMC) as the stealth division of the nation’s construction industry. At that time, PMC accounted for roughly $2 billion in annual revenues in North America. Five years later, industry revenues are well in excess of $3 billion and drive approximately $6 billion of construction activity. Based on a combination of industry survey data and data characterizing construction starts, projects using PMC technologies accounted for 3.18% of the value of commercial construction starts in the six key North American segments of commercial housing, education, institutional, healthcare, office and administrative, and commercial retail. Of the 3.18%, commercial housing captured 3.02% of the PMC market share.” (Sage, MBI, 2017)

The advantages of the modular construction over the traditional construction process are:
- Standardized work processes in a conditioned space without weather being a factor
- Secure environment for material storage and easier access to tools and few material deliveries
- Streamlined procedures resulting in less waste and greater optimization of materials and workers
- Significant reduced construction time due to modules being fabricated off-site at the same times as permits and site preparation activities are taking place

General stages involved in modular construction

Modular construction is a process of assembling building components that are fabricated offsite and then transported to be installed on a construction site. The building components/modules are quickly be assembled with the integration of plumbing, HVAC, and electrical wiring. The process of modular construction is very simple when compared to the conventional process of construction with the only complexity being the skills required to connect the modules with the mechanical services and to mate the seams of the interior finishes perfectly. The modular construction process can be divided into following stages:
- Design & Engineering
- Permits & Approvals
- Site Development
- Off-site Fabrication
- Transportation & Installation

Design and Engineering

The modular construction company requires detailed information about the client’s requirements in the early stages of the modular process. Table 1 presents an example checklist that helps designers understand the requirements of the client (7 Easy steps to Modular Construction):

Once the client’s requirements are understood, the modular construction company’s design team drafts detailed plans and specifications based on the building codes at the construction site’s location. Building codes are a set of rules and regulations whose primary purpose is to protect the health and safety of the general public and building’s occupants via proper design and construction methods (MBI 2015). Every country has its own set of building codes at the national, state and local levels. These codes ensure the safety standards and special considerations (urban design; height restrictions; natural hazards; proximity to water bodies; conservation requirements). Modular building construction has to undergo the same scrutiny at state and local levels as conventional construction. However, much of the inspection can take place during the fabrication of the modules. Modular construction follows the comprehensive set of building codes established by the International Code Council (ICC) for permanent construction and chapter 13 of the International Existing Building Code (IEBC) for relocatable modular buildings (i.e. portable classrooms, offices, emergency housing/disaster relief).

Although the modules are fabricated off-site, they can be customized in terms of design. Any kind of architectural style can be created by understanding its limitations. Architects develop the floor plans, interior and exterior designs, and specifications for the modular building. Some of the key considerations while designing the modules are:
- Module widths are typically 8, 10, 12, 14, 16 feet due to department of transportation restrictions. Although the length of modules is permitted up to 80 feet, 60 feet is the most commonly used length for transporting modules (Modular size: Maximum Length, Width, and Height 2013).
- The maximum permissible height of a module along
with the height of the trailer bed is 14’ with consideration of highway overpasses. Sloped roofing is created on the modules with hinges to fold them flat during transportation and erected once positioned on site (Modular home section).

- Jig sizes based on standard dimensions allows for easy workability, reducing time and material waste during production. Jigs form the basic pattern of design replicability. There is no limit to the scale of a project because these individual modules can be stitched together on site forming a large structure.
- Designing based on a grid system helps standardize the sizes of the modules; allows for better dimensional accuracy; and ensures modules will fit properly together when installed at the jobsite.
- Modular construction lends itself very well to repetitive spaces in a building such as bathrooms, hotel rooms, prison cells, dormitory rooms, etc. The larger the number of repetitive modules that can be constructed using standardized dimensions, the more economical the cost.
- When a client wants a specific design that cannot be transported due to size restrictions, the offsite fabricated components can be incorporated with the rest of the building that is constructed using conventional methods.
- Modules can be constructed with wood, steel framing and concrete.

### Permits & Approvals
A permit is a mandatory document required for the construction or renovation of a building that secures the building’s value, improves safety and reduces the potential concerns of unsafe construction. Some of the common permits required are: building permit, erosion control permit, encroachment permit, and flood permit to name a few. In most cases, the general contractor has the responsibility to obtain the permits and the client needs to make sure that the permits have been obtained. (7 Easy steps to Modular Construction)

### Site Development
Site development and foundation work in modular construction occur parallel with fabrication of the modules at the manufacturing plant, which saves a lot of field construction time as compared to the conventional

---

**Table 1: Checklist to Determine the Client’s Requirements for Designing a Modular Building**

<table>
<thead>
<tr>
<th>Item</th>
<th>Remarks</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Budget for the project</td>
<td>____ $</td>
<td>It decides the class of the project</td>
</tr>
<tr>
<td>Status of the land</td>
<td>Acquired/Not Acquired</td>
<td>To reduce inventory</td>
</tr>
<tr>
<td>Type of occupation</td>
<td>Temporary/Permanent</td>
<td>Decides the type of modular construction</td>
</tr>
<tr>
<td>What is the time frame for occupation?</td>
<td>____ Months</td>
<td>Helps to decide the priorities</td>
</tr>
<tr>
<td>Number of people to be accommodated in the project</td>
<td>____ persons</td>
<td>To decide the space requirements</td>
</tr>
<tr>
<td>Built up area requirement</td>
<td>____ Sq. Ft.</td>
<td>Decides the budget and compliance with building code.</td>
</tr>
<tr>
<td>Number of bathrooms</td>
<td></td>
<td>Plays a significant role in cost of the project</td>
</tr>
<tr>
<td>Fire suppression system</td>
<td>Required/Not required</td>
<td>Fire norms requires special attention.</td>
</tr>
<tr>
<td>ADA Compliant</td>
<td>Required/Not required</td>
<td>Designers have to create additional details to address disabled persons.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Remarks</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation of the building</td>
<td>North/ East/ West/ South</td>
<td>Helps to design the building according to climatology.</td>
</tr>
<tr>
<td>Type of exterior finish</td>
<td></td>
<td>Budget considerations</td>
</tr>
<tr>
<td>Type of interior Finish</td>
<td></td>
<td>Budget considerations</td>
</tr>
<tr>
<td>Type of flooring</td>
<td>Tile/ Carpet/ Stone</td>
<td>Budget considerations</td>
</tr>
<tr>
<td>Type of foundation</td>
<td>On grade/ Raised</td>
<td>Budget considerations</td>
</tr>
<tr>
<td>Type of roof</td>
<td>Sloped/ Flat</td>
<td>Design and budget considerations.</td>
</tr>
<tr>
<td>Number of modules required</td>
<td></td>
<td>Influences schedule, transportation and budget</td>
</tr>
</tbody>
</table>
building process in which these processes are sequential. As the number of modular components increases, the time taken to finish the project decreases. Figure 1 shows the time savings in percentage for different types of off-site construction methods as compared to the conventional construction process (Lawson, Ogden, & Goodier 2014).

![Figure 1: Comparative Construction Time for Off-site Methods](image)

The foundation system is selected based on the design of the modular building. If the construction is permanent type then a grade foundation is chosen that may utilize a slab-on-grade, pier foundation, or full foundation system. Raised foundations are typically selected for relocatable modular buildings which are designed to be moved from one location to another (i.e., portable classroom structures).

**Offsite Fabrication**

The process of fabricating modules off site happens in a controlled and planned way as the example below illustrates:

- Framing members are received from a steel shop or built in place using jigs (templates) to ensure correct dimensions. Once the structure is formed, the sub-floor is installed.
- The frame is now attached with the wall sections and a framing inspection is performed.
- The roofing system is built separately at ground level and then attached to the modules.
- The modules are then equipped with mechanical, electrical and plumbing lines and then final insulation is installed after the MPE inspections are performed.
- The installation of windows, doors and interior works happen simultaneously to save time.
- Once the above processes are completed and are inspected again, the modules are prepared for transportation.

**Transportation and Installation**

The transportation of the modules is done in multiple shipments. A maximum distance of 500 miles is used as a rule of thumb for the distance between the job site and the fabrication plant (Ryan E. Smith 2016). There are special third party carriers for transporting modules from the manufacturing plant to the construction site. There are different transportation limitations for the size of the modules from state to state. Special permits are required when the height of the structure exceeds 16 feet (SCDOT 2017). Minimum and maximum clearances to allow for transport of modular units are:

- Road width: 15'-0” min.
- Overhead clearance: 14'-0” min.
- Power line clearance: 15'-0” min.
- Carrier axle clearance: 14” max.
- Slope on access ways: 12” in 20’ max.
- Bridge weight limit: 15-ton min.
- Approaches to exits, bridges and underpasses must be long and wide enough to accommodate a 75’ tractor trailer/transporter.

The foundation and any other site work pertinent to the construction of the building must be completed before the modules arrive. Installation of modules is done with the help of a crane and a specialized workforce called "setters. The responsibility of installing the modules on site using cranes is determined during the contract negotiations (Ryan E. Smith, 2016). Once the modules are placed and mated together, mechanical, electrical and plumbing connections are made to the existing site utilities. Exterior siding and trim is completed and interior finishes are joined together seamlessly. Landscaping and hardscaping complete the final activities for a modular building no different than a conventionally constructed building.

**CASE STUDY**

This case study presents the design considerations for transforming an apartment building that was designed and constructed using conventional methods to one that could be built using the modular construction process. Figure 2 shows the exterior elevation and the floor plan of the original apartment building that will be used as a basis for modular construction adaptation for this case study. The three-story apartment building consists of 12 one-bedroom each 964 sf and 12 two-bedroom units each 1,312 sf. The overall exterior dimensions of the apartment building are 162'-4” long by 72'-4” wide. Table 2 shows the dimensions for the original apartment building used for this case study.
There could be several possible options in terms of design in modular construction. The basic principal of modular construction is to reduce the variety of modules and number of modules for repetitive cost efficient design. For this case study, three possible design options are presented with all 2 BR and 1 BR apartment modules having the same sizes of spaces. Also, the use of exterior and interior materials are kept the same as in the original apartment building design in order to illustrate that these do not have to be changed or sacrificed when using off-site fabrication.

Table 2: Dimensions of Original Apartment

<table>
<thead>
<tr>
<th>Type of apartment</th>
<th>Length in feet</th>
<th>Width in feet</th>
<th>Area in square feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 BR</td>
<td>44’-4”</td>
<td>36’-8”</td>
<td>1312</td>
</tr>
<tr>
<td>1 BR</td>
<td>30’-2”</td>
<td>36’-8”</td>
<td>964</td>
</tr>
<tr>
<td>Corridor</td>
<td>38’</td>
<td>8</td>
<td>304</td>
</tr>
<tr>
<td>Staircase</td>
<td>18’</td>
<td>8</td>
<td>144</td>
</tr>
</tbody>
</table>

Figure 3 Option 1 Basic Block Design reflects a typical image of a building plan when people think of modular construction. There isn’t too much extra effort in terms of designing using a basic block layout. The use of a rectangular outline simplifies design, fabrication and cost of the modules. Unlike the original apartment design, the balconies are positioned at corners for better viewing angles. It is also important to have the bathrooms as independent modules rather than splitting the bathrooms into two separate modules. The floor plans are mirrored to reduce the complication and time in the fabrication process. A minimal number of modules saves assembly time on site. This option may impress the developers, but it may not be too appealing in terms of exterior aesthetics. A typical floor plan is adopted to design this option for three levels. Each floor consists of eight units made up of sixteen modules and every two modules make one apartment unit of 2 bedroom (BR) or 1 BR:
Designing a Modular Building: A Case Study for Modular vs. Conventional Design for an Apartment Building

Figure 3: Option 1 Basic Block Design Floor Plan and Elevation

- Total number of modules per floor = 20
- Total number of modules in the entire building = 60
- Types of modules in the building = 6 (2 for 2BR, 2 for 1 BR, 1 for corridor, 1 for staircase)

In the multi-family modular industry, the standard widths used are twelve, fourteen and sixteen feet, and the selection of length of module is based on state department of transportation requirements. Table 3 shows the exterior dimensions of the different modules for option 1.

![Figure 4: Option 1 - Alignment of Modules in 2 BR units](image)

**Table 3: Module Sizes for Option 1**

<table>
<thead>
<tr>
<th>Type of module</th>
<th>Length in feet</th>
<th>Width in feet</th>
<th>Apartment Area in SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modules in 2 BR (2)</td>
<td>50</td>
<td>12</td>
<td>1,200</td>
</tr>
<tr>
<td>Modules in 1 BR (2)</td>
<td>39</td>
<td>12</td>
<td>936</td>
</tr>
<tr>
<td>Corridor module</td>
<td>25</td>
<td>8</td>
<td>200</td>
</tr>
<tr>
<td>Staircase module</td>
<td>12</td>
<td>8</td>
<td>96</td>
</tr>
</tbody>
</table>

Figure 4 Alignment of Modules in 2 BR units shows how modules in the 2 BR units are joined together. The grid lines of 2 BR and 1 BR units are aligned to achieve maximum stability to the structure. Besides the apartment modules, there are two modules for corridor spaces and two staircase modules. Corridor modules are attached to the adjacent modules and tie all the units together. The staircase and corridor modules can be supported by self-supporting steel structures with the support of the ground or they can be attached to the adjacent modules.

![Figure 3: Option 1 Basic Block Design Floor Plan and Elevation](image)
Figure 5 shows the Option 2 floor plan and elevation of a multiple terrace concept that enhances the overall aesthetics and user experience of the modular building. The quality of the spaces is more focused in this option with a departure from a boxy design. The balconies are split into three for each apartment unit to achieve private balconies for the bedrooms and a separate balcony for the living area. This option could be a little more complicated than Option 1 due to the increased number of modules, but the design may be more aesthetically and functionally pleasing to a client. A typical floor plan is adopted to design this option in three levels. Each floor consists of eight units made up of twenty modules and every three modules makes one apartment unit of 2 BR or 1 BR.

- Total number of modules per floor = 24
- Total number of modules in the entire building = 72
- Types of modules in the building = 8 (3 for 2 BR, 3 for 1 BR, 1 for corridor, 1 for staircase)

Although there are three types of modules for making one apartment unit, the modules are mirrored to maintain the same design throughout the floor plan and lessen the complexity of dealing with different designs. Table 4 shows the exterior dimensions of the different modules for option 2. Figure 6 shows how modules in Option 2’s 2 BR units are joined together. The grid lines of 2 BR, 1 BR units, corridor and staircase are aligned to achieve maximum stability to the structure and lesser complexity during installation to the structure. Similar to the previous option, the corridor
modules are attached to the adjacent modules in the floor plan and the staircase is a self-standing structure with the support of ground.

Table 4: Module Sizes for Option 2

<table>
<thead>
<tr>
<th>Type of module</th>
<th>Length in feet</th>
<th>Width in feet</th>
<th>Apartment Area in SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Module in 2 BR</td>
<td>28</td>
<td>11</td>
<td>1,470</td>
</tr>
<tr>
<td>2nd Module in 2 BR</td>
<td>43</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>3rd Module in 2 BR</td>
<td>40</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>1st Modules in 1 BR</td>
<td>30</td>
<td>16</td>
<td>984</td>
</tr>
<tr>
<td>2nd Modules in 1 BR</td>
<td>36</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Corridor module</td>
<td>30</td>
<td>8</td>
<td>240</td>
</tr>
<tr>
<td>Stair case module</td>
<td>12</td>
<td>8</td>
<td>96</td>
</tr>
</tbody>
</table>

The staircase and corridor modules are supported by self-standing steel structures with the support of ground. Figure 8 shows the stacking of all the apartment modules and the two façade elements that have to be constructed separately from the apartment modules due to the difficulty of mate-line stitching in the field.

As per modular construction standards, a clear height of 10 feet is maintained on all the floors as shown in Figure 9.

Figure 11 shows a graphical representation of an Option 3 module getting installed on site. The foundation should be in place before the modules arrive on site to avoid delays. Cranes, slings and belts connected to pick points on the module itself are used to lift and maneuver the module into its final position. Once the module has been set in place, watertight joints are sealed, bolted, glued or overlapped where modules connect together. Mateline stitching is the process of covering up seams on the exterior and interior of the modular building. Seams can

for 1 BR, 1 for corridor, 1 for staircase, 2 façade modules)

The number of modules are minimal in this option due to the reasons mentioned earlier. The floor plans are mirrored like the ones shown in options 1 and 2. Table 5 shows the exterior dimensions of the different modules for option 3.

Table 5: Module Sizes for Option 3

<table>
<thead>
<tr>
<th>Type of module</th>
<th>Length in feet</th>
<th>Width in feet</th>
<th>Apartment Area in SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modules in 2 BR (2)</td>
<td>45</td>
<td>16</td>
<td>1,440</td>
</tr>
<tr>
<td>1st Module in 1 BR (1)</td>
<td>31</td>
<td>16</td>
<td>899</td>
</tr>
<tr>
<td>2nd Module in 1 BR (1)</td>
<td>31</td>
<td>13</td>
<td>256</td>
</tr>
<tr>
<td>Corridor module</td>
<td>32</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Stair case module</td>
<td>12</td>
<td>8</td>
<td>96</td>
</tr>
<tr>
<td>Façade element - 01</td>
<td>36</td>
<td>14</td>
<td>N/A</td>
</tr>
<tr>
<td>Façade element - 02</td>
<td>25</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>
Figure 7: Option 3 Original Case Study Conversion Floor Plan and Elevation

Figure 8: Two Facade Elements and Stacking of Modules
be incorporated into the overall aesthetic design of the building (i.e., trim pieces). The materials chosen for the façade of Option 3 shown in Figure 12 align with the case study apartment building:

- Cultured stone veneer on the ground level exterior walls
- Fiber cement horizontal siding on the first level exterior walls
- Fiber cement shake paneling on the second level exterior walls
- Arched stone headers
- Fiber cement panels (for elemental columns) columns
- Wooden brackets, and Fiber cement batten stripes
- Trim: Fiber cement
- Breezeways: Vinyl soffit on the ceilings, exposed concrete flooring on the ground floor and wooden decking on the first and second floors.

CONCLUSION

Table 6 shows the comparison of the three design options developed from the original case study apartment building which depicts the various pros and cons of designing a modular building. Option 1 shows a typical modular approach without any experimentation in design. Option 3 is an example to show how a conventionally constructed apartment building can be designed with a modular approach without any changes to the initial design and aesthetic appeal. To achieve a highly flexible design in modular construction, an architect may have to increase the number of modules or create a flexible grid. Designing a modular building can be challenging and aesthetically pleasing and not as restrictive as one would imagine. Understanding the constraints and possibilities acts as a driving force to come up with innovative and sustainable designs. Modular buildings contribute to sustainability/green building in the following ways:
Table 6: Comparative Analysis of the Three Options

<table>
<thead>
<tr>
<th></th>
<th>Original</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design focus</strong></td>
<td>Traditional non-grid layout</td>
<td>Boxy Layout</td>
<td>Addition of contemporary design features to the original design</td>
<td>Maintaining the exact design of the original building</td>
</tr>
<tr>
<td><strong>Grid</strong></td>
<td>No Grid</td>
<td>Strong grid pattern without any experimentation</td>
<td>Flexible grid</td>
<td>Moderately flexible grid</td>
</tr>
<tr>
<td><strong>Design flexibility</strong></td>
<td>Low</td>
<td>High</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td><strong>Total number of modules in the entire building</strong></td>
<td>N/A</td>
<td>60</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td><strong>Types of Modules involved in the building.</strong></td>
<td>N/A</td>
<td>6</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td><strong>1 BR Area</strong></td>
<td>964 sf</td>
<td>936 sf</td>
<td>984 sf</td>
<td>899 sf</td>
</tr>
<tr>
<td><strong>2 BR Area</strong></td>
<td>1312 sf</td>
<td>1200 sf</td>
<td>1470 sf</td>
<td>1440 sf</td>
</tr>
<tr>
<td><strong>Corridor Area</strong></td>
<td>304 sf</td>
<td>200 sf</td>
<td>240 sf</td>
<td>256 sf</td>
</tr>
<tr>
<td><strong>Staircase Area</strong></td>
<td>144 sf</td>
<td>96 sf</td>
<td>96 sf</td>
<td>96 sf</td>
</tr>
</tbody>
</table>

- Material waste is minimized using pre-dimensioned jigs
- Impact on site environment is reduced (dust, noise, congestion)
- LEED requirements and International Green Construction Code can be followed
- The number of people, vehicles and construction site is reduced

Architects and clients should be encouraged to explore the use of modular construction when appropriate. Design issues are not necessarily restricted; the owner can have a functioning and profitable facility in less time than conventional construction; and the general contractor will have reduced field overhead costs and be able to complete the project faster than conventional construction.

REFERENCES


Lawson, Ogden, & Goodier. (2014). Design in Modular Construction: Examples of levels of off-site manufacture (OSM). Boca Raton, FL: Taylor and Francis Group, LLC.


Examining the Microeconomics of Bid Difference of Engineer & Contractor Bids in Highway Construction

Robert Ryan*, Randy R. Rapp, Mark Shaurette, and Sarah Hubbard
Purdue University | ryan92@purdue.edu

ABSTRACT

This study examines microeconomic factors that affect Bid Difference between the designer’s Engineer’s Estimate and the contractor’s Winning Bid. Historically, the accuracy of the Engineer’s Estimate and the Winning Bid vary. To account for this discrepancy, the Federal Highway Administration (FHWA) recommends a contingency be included in all Engineer’s Estimates. Statistical analysis was performed to determine if state Departments of Transportation (DOTs) were currently meeting the recommended Bid Difference values. Data was collected from California, North Carolina, and Ohio from 2012 through 2014. Statistical analysis indicates that current practices to develop an Engineer’s Estimate met the FHWA recommended values. With the use of Pearson Correlation and Linear Regression, statistical analysis was performed to determine what factors may affect Bid Difference. The research suggests that competition based microeconomic factors affected Bid Difference, and these factors were not accounted for in the Engineer’s Estimate. The results of linear regression analysis suggest that when these factors are not included in the Engineer’s Estimate, the Bid Difference is more likely to exceed the FHWA recommended contingency.

Keywords: Bidding, Estimating, Accuracy, Engineer’s Estimate, Recession

Robert Ryan CPC, is an Ph.D. candidate in the School of Construction Management Technology at Purdue University in West Lafayette, Indiana. In addition, he works as an Estimator for Superior Construction’s Midwest Business Unit.

Randy R. Rapp, D.Mgt., P.E., C.C.P., M.ASCE, is an Associate Professor of Construction Management Technology at Purdue University. He has managed construction operations and support functions from jobsite to executive office, in the public and private sectors, at home and abroad, about half of his 40-plus year career.

Mark Shaurette is an Associate Professor at Purdue University. In addition to a MS in Civil Engineering from Massachusetts Institute of Technology and a Ph.D. from Purdue University, has 30+ years of construction industry experience.

Sarah Hubbard is a professional engineer and assistant professor in the Purdue Polytechnic School of Aviation and Transportation Technology.
INTRODUCTION

Before a highway construction project is advertised for bidding, Departments of Transportation (DOTs) create an estimate to determine an approximate budget for the project. This estimate is referred to as the Engineer’s Estimate. This project is advertised for bidding, and generally, multiple contractors bid on the project. The project is awarded to the bidder with the lowest total dollar value. If this bid is deemed the lowest responsive and responsible bid, it is referred to as the Winning Bid. If the Winning Bid is deemed excessive in price, the project is often rebid until the Winning Bid is closer to the Engineer’s Estimate.

The contractor’s process to develop a Winning Bid is different from the process to develop an Engineer’s Estimate. The contractor must prove that they are responsive and responsible in their bidding practices. This means that a responsive bidder must adhere to the contract documents and must not have any irregularities in the bid’s unit pricing. To be considered responsible, contractors must prove they that are competent in the work they are bidding. In other words, they must be familiar with the work, have performed similar work, and are able to allocate the proper resources to perform the work. To prove their responsiveness and responsibility, and to ensure that they can build the project successfully with the desired profit margin, it is a common assumption that contractors who are competitively bidding for a project create the estimate at a higher level of detail and accuracy. This level of detail and accuracy is not used when engineers develop the Engineer’s Estimate, which is used for budget and planning purposes. Despite the high level of detail that goes into the contractor bids, the lowest priced estimate may not be awarded the project if the apparent Winning Bid exceeds the less detailed and less accurate Engineer’s Estimate. The difference between the apparent Winning Bid and the Engineer’s Estimate is referred to as Bid Difference and is often expressed in percentages.

The research dataset covers three complete years (2012 - 2014) from three State DOTs across the US. The total contract award volume represented over this three-year period is more than eleven billion dollars. This unique dataset represents the Heavy Highway industry during the final year of the Great Recession and the following two years of recovery.

To better understand the relationships examined in this research, the microeconomic factors present at bid time are examined. Microeconomics examines the behavior of firms making decisions regarding the allocation of scarce resources and the interactions among firms. This research examined the practices used to create the Engineer’s Estimate versus the practices used by the contractor to create the Winning Bid. Bid data from state DOTs were collected and analyzed to determine if state DOTs met the Federal Highway Administration’s (FHWA) recommended levels of bidding accuracy for the Engineer’s Estimate. Through literature review, microeconomic factors present at bid time were established. These microeconomic factors were examined to determine their possible relationships and interactions. The research aims to examine if these microeconomic factors principles had indirectly affected bid pricing due to the Great Recession and subsequent recovery period. Specific factors included: Number of Bidders, Disadvantaged Business Enterprise (DBE) Participation Goal, Contract Size, Quarter (i.e., fall, spring, etc.) and Year. Using the statistical analysis presented in this research, a better understanding of pricing beyond what is represented by historical bid based data can be established. This understanding has the potential to guide DOTs to better determine the reliability of the Engineer’s Estimate, as well as to anticipate opportunities that may lower bid pricing.

It is worth noting that the intent of this paper is to examine the relationship existing for award criteria only. This research examines the Winning Bid and Engineer’s Estimate at bid time. This research omits any investigation of additional impacts that may affect the total cost of the project, including quantity increases/decreases, change orders, delays, etc.

LITERATURE REVIEW

The importance of creating an accurate estimate is imperative to both the contractor and the DOT. A successful estimate must be an accurate one, meaning that the estimate needs to be sufficiently close to as-constructed planning, production, and costs. To be accurate, one must mentally construct the project on paper before it is constructed in real life (Carr, 1989). To mentally construct the project, an accurate estimator must use their previous experience to capture all components such as labor, equipment, material, subcontractors, overhead, and profit (Choi, 2014). Experience in estimating is key to the
The importance of creating an accurate estimate is essential for company survival for a contractor. Costs must accurately account for the project’s components, but must not be excessive in order to remain competitive (Choi, 2014). There is a fine line between carrying too much cost, and not enough cost to build a successful estimate. If all costs are not considered, a project can be underpriced, which will result in profit erosion for the company. Similarly, if profit erosion is too great in value, or too great in frequency, this will eventually force the contractor out of business. If the estimate is bid too high, the contractor will not win the bid, eroding backlog and eventually leading to business failure. To reduce this risk, contractor estimates are often compiled with a team of experienced estimators who are familiar with the work at hand. These estimates are reviewed by executive level management to determine if there are any errors or omissions in the estimate. Costs are thoroughly reviewed for each specific scenario as factors, such as type of work, size of project, location, site conditions, and level of competition which can increase or decrease the unit costs of each individual project. Unlike residential or commercial projects, where multiple projects can be built from “cookie cutter” type plans, Heavy Highway projects are especially unique. Accordingly, each project requires extensive experience, attention to detail, and a desire for accuracy to complete an accurate estimate for a Heavy Highway project. Contractors must take a responsible approach in developing a Winning Bid. It is essential to the company’s survival. Any other approach would be considered irresponsible.

The FHWA handbook, Guidelines on preparing engineer estimates, bid reviews and evaluation (2004) states that DOTs create Engineer’s Estimates for two reasons: to allocate monetary and management resources for multi-year program funding and to ensure a fair price is received during the bidding process. This estimate is created by the design engineer and the FHWA recommends that the estimate should be refined throughout the design process, first as a conceptual estimate and finally as an anticipated cost, also called the Engineer’s Estimate. The Engineer’s Estimate acts as the price check at bid time for each contractor’s bid. The FHWA classifies the estimating methods of the Engineer’s Estimate into one of three methods. The first method, called an actual-cost approach, is a method similar to that of a contractor. Extensive detail is used to determine the actual costs of the project. The second method, called a historical bid-based approach, utilizes historical unit prices for each line item cost component listed in the contract. These outdated unit prices are used as the comprehensive unit cost of the item. No additional consideration is given to determine any increased or decreased complexities or change of scenarios for the current project. The third method, called the mix-method approach, combines the actual-cost and historical bid-based approaches to create an estimate. Very few Engineer’s Estimates are created using actual cost approach. In Report Number: MH-2013-012A, the FHWA’s Office of the Inspector General (OIG) Surveyed 51 DOTs in 2012. This study found only 1 out of the 51 DOTs develop an Engineer’s Estimate with the same level of detail and accuracy as a contractor that develops a Winning Bid.

These findings should come as no surprise to those with experience in this sector of the industry. It has been widely recognized that a lack of resources, a lack of estimating experience, and time requirements for DOTs often leave the design engineer unable to create an accurate Engineer’s Estimate (Alroomi 2012; Wilmot & Cheng, 2003; Shane, Molenaar, Anderson, & Schexnayder, 2009). To account for this accuracy discrepancy, the FHWA recommended a 10% contingency be included in the Engineer’s Estimate. This contingency serves to offset the Bid Difference in the accuracy of the Engineer’s Estimate and the Winning Bid. Moreover, the FHWA defines an accurate bid as one that is within ±10% of the Winning Bid (Federal Highway Administration, 2004). Additionally, the FHWA also includes a non-regulatory guidance to check the state program’s estimating methods to ensure that at least 50% of the projects awarded should be within the ±10% contingency for the estimating program to be considered accurate.

During the Great Recession, Heavy Highway contractors experienced increased competition. Not only were contractors competing against traditional competitors, they were also bidding against commercial contractors that entered the Heavy Highway sector. This increased competition was due to the reduced commercial contracting opportunities (Danforth, Weidman, & Farnsworth, 2017). Due to increased competition and an eroding backlog, contractors were forced to reduce marginal and fixed costs to win bids. These cost reductions were needed to maintain cash flow, keep employees, equipment, and other resources utilized during this period (Tansey, Meng, & Cleland, 2014). Methods to reduce marginal costs
profits must be limited in order to lower or maintain prices and therefore deter new competitors from entering the market. This concept of new competitors can be applied to the building contractors that entered the Heavy Highway market during the Great Recession.

Porter’s second force, the intensity of rivalry, is considered the force with the highest potential to limit the profitability of an industry. The intensity of rivalry is greatest when competitors are numerous or are similar in size. When this occurs, profit is eroded due to the reduction of price points and profits being directly removed from the industry to its customer. It is this force that creates the scenario that is researched in this paper. Price cuts are a common method to erode profit when fixed costs are high and marginal costs are low. It is of significance to point out that the contractor’s profits are included in their unit prices, thus reducing the present costs at bid time. These present costs will eventually become historical unit prices at a future date. The concept of intensity of rivalry can be applied to contractors trying to build or create their backlog. If same size competition is fierce, it will limit the buildup of backlog. To restore backlog, one can assume contractors are likely to limit their markup until they have a sufficient backlog.

The methods competitive contractors use to create a Winning Bid and the method designers create an Engineer’s Estimate are significantly different in the level of detail and thought required to be considered an accurate bid. A contractor may spend weeks or months preparing a Winning Bid, whereas a designer may spend hours creating an Engineer’s Estimate. It is the contractor’s responsibility to create an accurate Winning Bid, whereas the designer is allotting a discretionary dollar value to a program budget. The current authors examine the accuracy of the Engineer’s Estimate and which microeconomic factors affect the accuracy of the bid results.

METHODOLOGY

To determine if Engineer’s Estimates capture actual market conditions, bid results for three years of available data were analyzed. These years included 2012, 2013, and 2014. This point in time is of interest given that the construction industry was slowly climbing out of the Great Recession. It is of significance to note that Bureau of Labor Statistics (BLS) classified the end of the Great Recession as December 2009. However, the construction
industry did not recover until 2012 (Henderson 2016). State DOT programs were selected based on their total funding received by the FHWA, as listed in Table 1. The top 10 states receiving FHWA funding were selected for analysis. Freedom of Information Act (FOIA) requests were issued at the state level.

Table 1: Total FHWA Funding (as expressed in thousands of dollars) for the top 10 states for 2012-2014.

<table>
<thead>
<tr>
<th>State</th>
<th>Total</th>
<th>Yearly Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>CALIFORNIA</td>
<td>$10,624,447</td>
<td>$3,541,482</td>
</tr>
<tr>
<td>TEXAS</td>
<td>$9,706,493</td>
<td>$3,235,498</td>
</tr>
<tr>
<td>FLORIDA</td>
<td>$5,484,549</td>
<td>$1,828,183</td>
</tr>
<tr>
<td>NEW YORK</td>
<td>$4,858,913</td>
<td>$1,619,638</td>
</tr>
<tr>
<td>PENNSYLVANIA</td>
<td>$4,749,491</td>
<td>$1,583,164</td>
</tr>
<tr>
<td>ILLINOIS</td>
<td>$4,115,549</td>
<td>$1,371,850</td>
</tr>
<tr>
<td>OHIO</td>
<td>$3,880,140</td>
<td>$1,293,380</td>
</tr>
<tr>
<td>GEORGIA</td>
<td>$3,737,680</td>
<td>$1,245,893</td>
</tr>
<tr>
<td>MICHIGAN</td>
<td>$3,047,777</td>
<td>$1,015,926</td>
</tr>
<tr>
<td>NORTH CAROLINA</td>
<td>$3,017,189</td>
<td>$1,005,730</td>
</tr>
</tbody>
</table>

Each FOIA request included the following data; Date, Engineer’s Estimate value, Winning Bid value, Contract ID, DBE Participation Goal, and Number of Bidders. Other data was formulated, which included State, Bid Difference, calculated as:

\[
\text{Bid Difference} = \frac{\text{Winning Bid} - \text{Engineer's Estimate}}{\text{Winning Bid}} \times 100\%
\]

Quarter, and Year. Data was returned for 5 states, and included complete datasets for 3 states: California, North Carolina, and Ohio. The data was grouped and analyzed by state. Engineer’s Estimates contracts of less than $1,000,000 were excluded from the data set. The data set analyzed included a total of 1,727 contracts. Simple statistics were formulated and summarized to determine whether bid accuracy was in the FHWA’s recommended limits.

Following the statistical summary review, the research focused on determining correlation and relation of the microeconomic variables and Bid Difference. Once the calculated and properly-formatted data set was compiled, the data was uploaded into IBM SPSS for statistical analysis. As Bid Difference is the determinant variable between the Engineer’s Estimate and Winning Bid, Bid Difference was compared using Pearson Correlation. Pearson Correlation is formulated as the covariance of the two variables divided by the product of their standard deviations. Values of -1 to 1 are associated with Pearson Correlation to indicate the strength of the relationship. A linear regression was created for each state to examine the relationship present between the previously mentioned microeconomic factors and Bid Difference.

FINDINGS

Before any analysis was performed, a scatter plot was created to visually check the distribution relative to a normal distribution. The scatter plot suggests that Bid Difference was normally distributed with a slight right skew. This skew was anticipated based on the potential for Winning Bids below 10% of the Engineer’s Estimate to be awarded, as well as the unlikelihood for Winning Bids above 10% of the Engineer’s Estimate to be awarded. Descriptive statistics are shown on Table 2.

Bid Difference was totaled for all three states and for each individual state. There was a total of -4.74% Bid Difference, with the data ranging from -8.35% in NC to +3.38% in OH as shown on Table 3. The accuracy of the Engineer’s Estimate was determined to be within the FHWA’s recommendations.

Table 2: Summary statistics of contract values for California, North Carolina, and Ohio DOTs.
Table 3: Summary statistics Bid Difference.

<table>
<thead>
<tr>
<th>STATE</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA</td>
<td>-6.5%</td>
<td>-5.1%</td>
<td>-6.2%</td>
<td>-6.0%*</td>
</tr>
<tr>
<td>NC</td>
<td>-8.4%</td>
<td>-5.1%</td>
<td>-4.0%</td>
<td>-6.0%*</td>
</tr>
<tr>
<td>OH</td>
<td>3.4%</td>
<td>-3.7%</td>
<td>-0.8%</td>
<td>-1.8%*</td>
</tr>
<tr>
<td>TOTAL</td>
<td>-6.5%</td>
<td>-4.5%</td>
<td>-4.0%</td>
<td>-4.7%*</td>
</tr>
</tbody>
</table>

*Weighted averages of cumulative state values

The data was then analyzed to determine if the projects were in accordance with the FHWA recommendation of program accuracy. Based on the results shown in Table 4, California did not meet the FHWA’s recommendations. North Carolina and Ohio were within the acceptable range of program accuracy. As shown in Figure 1, 41.9% (724) of the contracts awarded were outside of the ±10% range. Additionally, of those contracts outside of the ±10% range, 70.2% (508) were awarded below the -10% threshold.

Each state consistently awarded projects that were -10% or below the Engineer’s Estimates, at a ratio of nearly seven to three. It is likely that this nearly seven to three ratio was present due to the potential program savings, and policy constraints that prevented project awards when the Winning Bid was above the 10% contingency, which could result in a program deficit. This research does not include analysis of apparent Winning Bids that were rejected due to being outside of the ±10% range.

The analyses found varied levels of estimating accuracy, with a standard deviation of 2.8%. However, all state and annual award statistics were within the FHWA allowable estimating accuracy range. A time-series chart was created to support visual analysis of trends over time.

Despite meeting the FHWA accuracy limits, each state’s accuracy and trend varied, as shown in Figure 2, which plots the Bid Difference relationship for each state. California’s Bid Difference increased and then decreased while remaining negative. North Carolina’s Bid Difference steadily decreased while also remaining negative. Ohio’s Bid Difference started positive in 2012, decreased into the negative in 2013, and moved into the positive in 2014, closely approaching 0% Bid Difference. During the time this data was observed, contractors were reducing costs to meet the highly competitive market. It is important to note that in the period between 2010 and early 2012, the OIG noted there was an average 18% savings between the Engineer’s Estimate and the Winning Bid. From 2012 to 2014, more accurate Engineer’s Estimates were created, and savings were reduced to 5%. It is unclear how these estimates improved in accuracy since there have been no published changes to DOT estimating standards. Without a formal revision

Table 4: Summary of Contracts awarded outside of the FHWA recommended ±10% contingency.

<table>
<thead>
<tr>
<th>STATE</th>
<th>NUMBER OF BIDS</th>
<th>BIDS AWARDED OUTSIDE OF FHWA RANGE</th>
<th>PERCENT AWARDED OUTSIDE OF RANGE</th>
<th>NUMBER OF BIDS &lt; -10%</th>
<th>NUMBER OF BIDS &gt; +10%</th>
<th>PERCENT OF BIDS &lt; -10%</th>
<th>PERCENT OF BIDS &gt; +10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA</td>
<td>616</td>
<td>319</td>
<td>51.8%</td>
<td>221</td>
<td>98</td>
<td>69.3%</td>
<td>30.7%</td>
</tr>
<tr>
<td>NC</td>
<td>483</td>
<td>193</td>
<td>40.0%</td>
<td>161</td>
<td>32</td>
<td>83.4%</td>
<td>16.6%</td>
</tr>
<tr>
<td>OH</td>
<td>628</td>
<td>212</td>
<td>33.8%</td>
<td>126</td>
<td>86</td>
<td>59.4%</td>
<td>40.6%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1727</td>
<td>724</td>
<td>42.0%</td>
<td>508</td>
<td>216</td>
<td>70.2%</td>
<td>29.9%</td>
</tr>
</tbody>
</table>
to estimating standards, it is reasonable to assume there has been no change in Engineer’s Estimate approaches or methodologies. One plausible explanation for this significant improvement in accuracy is that the unit price averages used in the Engineer’s Estimate eventually reflected the market conditions in the Winning Bid. Simply put, the methodology did not change, the market did.

The methods that used “high” historical unit averages produced an improvement in accuracy over the two years and the “high” historical averages resulted in significant savings when costs were lowered during times of extreme competition. Table 5 provides a visual representation of the relationship of the lagging timeframe of acceptable historical data and the market conditions present during the creation of the Engineer’s Estimate. Table 5 illustrates the opportunities of utilizing extreme data to compile an Engineer’s Estimate, but still be within the acceptable time frame of data age. For example, 2008 historical bid data could have been used for an Engineer’s Estimate created in 2011. If the bid data had been created with historical bid pricing from the Great Recession, the estimate may have accurately represented the market within ±10%.

As shown by Table 6, Bid Difference values for each state correlated significantly with the Number of Bidders and Quarter. The Pearson Correlation output aligned with the previously mentioned scatter plot and supported the relationships expressed by the plots. In all three states, Bid Difference decreased as the Number of Bidders increased.

To examine the relationship between microeconomic variables, and Bid Difference, a linear regression was

![Figure 2: Time series data of Bid Difference by State](image)

Table 5. Historical data compiled and used for Engineer’s Estimates

<table>
<thead>
<tr>
<th>Year</th>
<th>04</th>
<th>05</th>
<th>06</th>
<th>07</th>
<th>08</th>
<th>09</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historical Data</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>F</td>
<td>F</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Date Data Used</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

H: Pre-Great Recession Era Pricing
L: Great Recession Era Pricing
C: Post-Great Recession Era Pricing
F: Future Pricing

Table 6. Summary of significance level for Pearson Correlation for each state.

<table>
<thead>
<tr>
<th>State</th>
<th>Pearson Correlation Score Bid Differences by:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NUMBER OF BIDDERS</td>
</tr>
<tr>
<td>California</td>
<td>-.211**</td>
</tr>
<tr>
<td>North Carolina</td>
<td>-.12**</td>
</tr>
<tr>
<td>Ohio</td>
<td>-.263**</td>
</tr>
</tbody>
</table>

** 0.01 level of significance
* 0.05 level of significance
created for each state. Each state linear regression consisted of the following formula:

\[
\text{BID DIFFERENCE( PERCENT )} = \beta_{\text{INTERCEPT}} + \beta_{\text{NUMBIDS}} + \beta_{\text{GOAL}} + \beta_{\text{WBSIZE}} + \beta_{2012} + \beta_{2013} + \beta_{2014} + \beta_{Q1} + \beta_{Q2} + \beta_{Q3} + \beta_{Q4}
\]

Each model included Number of Bidders (NUMBIDS), DBE Participation Goal (GOAL), Winning Bid Size (WBSIZE), Year (2012, 2013, 2014), and Quarter (Q1, Q2, Q3, Q4). Given the quantitative nature of NUMBIDS, GOAL, and WBSIZE, these variables were treated as covariates by SPSS. Year and Quarter were treated as fixed variables by SPSS. These fixed variables were compared to the baseline variables of 2014 and Q4. Each of these variables were used in the Pearson Correlation. To reduce the collinearity of Contract Size between the Engineer’s Estimate and Winning Bid, only the Winning Bid was used to represent the Contract Size. Since the Winning Bid is the more detailed approach, it was determined to be the indicating variable. The linear regression analysis resulted in the following relationship:

\[
\text{CA BID DIFFERENCE( PERCENT )} = 1.555 - 1.534_{\text{NUMBIDS}} + 0.150_{\text{GOAL}} + 0.051_{\text{WBSIZE}} + 0.195_{2012} - 1.003_{2013} + 0.000_{2014} + 1.035_{Q1} - 0.497_{Q2} + 3.169_{Q3} + 0.000_{Q4}
\]

\[
\text{NC BID DIFFERENCE( PERCENT )} = -10.954 - 1.264_{\text{NUMBIDS}} + 1.513_{\text{GOAL}} + 0.010_{\text{WBSIZE}} - 0.973_{2012} - 1.575_{2013} + 0.000_{2014} - 2.427_{Q1} + 3.147_{Q2} + 4.264_{Q3} + 0.000_{Q4}
\]

\[
\text{OH BID DIFFERENCE( PERCENT )} = -0.947 - 1.864_{\text{NUMBIDS}} + 1.028_{\text{GOAL}} + 0.010_{\text{WBSIZE}} + 1.031_{2012} - 2.429_{2013} + 0.000_{2014} - 1.682_{Q1} - 0.299_{Q2} + 3.721_{Q3} + 0.000_{Q4}
\]

A goodness-of-fit test was performed on each state’s linear regression model. Due to a large sample size and limited variables for examination, relatively low r-squared values were reported for all three models as indicated on Table 7. Clearly there are still other factors that need to be examined to fully understand the many impacts that affect Bid Difference.

Table 7. R-Squared and Adjusted R-Squared values for the linear regression models.

<table>
<thead>
<tr>
<th></th>
<th>CA</th>
<th>NC</th>
<th>OH</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-Squared</td>
<td>0.071</td>
<td>0.233</td>
<td>0.106</td>
</tr>
<tr>
<td>Adj R-Sq.</td>
<td>0.050</td>
<td>0.210</td>
<td>0.090</td>
</tr>
</tbody>
</table>

Linear regression analysis suggests that time related data, such as Year and Quarter have a larger impact on Bid Difference. These two variables could account for a 4-percentage point reduction (Q1 2013 in Ohio), or as great as a 4-percentage point increase (Q3 2014 North Carolina) in the Bid Difference. Median number of bidders also has a significant impact. Examining 4 bidders and the model in Table 2, an increase of 4 bidders can potentially decrease Bid Difference from 5 to 7.45-percentage points. When time related data and Number of Bidders is combined, a total of 9 to 11-percentage point decrease in Bid Difference is possible. It is important to note that Season, Year, and Number of Bidders are likely unknown when the Engineer’s Estimate is created.

Effects may be greater when compounded. For example, based on the model in Figure 3, for Q1 2013 in Ohio, a 6% DBE Goal may increase Bid Difference to approximately 6-percentage points, but the Q1 2013-time series would decrease Bid Difference by approximately 5-percentage points, resulting in a net change of a 1-percentage point.

The intent of the 10% FHWA contingency is to accommodate discrepancies between the estimating approaches of the engineer and contractor. Whether they increase or decrease Bid Difference, these variables, and their associations, are not considered in the creation of an Engineer’s Estimate. As such, these microeconomic factors and the effect of their relationships are not included in the 10% FHWA contingency. However, with these factors present in this data set, the microeconomic variables minimized Bid Difference. When these microeconomic factors are present, they have the potential to misrepresent the accuracy of the historical-bid based estimating approach, thus potentially misrepresenting accuracy of the Engineer’s Estimate.

Through Pearson Correlation and Linear Regression, previous research regarding the Number of Bidders effecting the Winning Bid is supported. As suggested by Porter (2008), it is safe to assume that as the Number of Bidders increased, the likelihood of carrying high profit and overhead decreased the likelihood of
being the lowest responsible bidder. Moreover, other concepts of competition are supported by the Pearson Correlation scores. North Carolina costs increased when subcontractor DBE Participation Goals increased. In this case, competition was reduced as the number of available subcontractors decreased, limiting the pool of available subcontractors.

**CONCLUSIONS AND RECOMMENDATIONS**

DOTs have a few options to reduce the Bid Difference in the contract award. The obvious option is to use a more detailed cost approach to develop Engineer’s Estimates. This option is unrealistic due to resource limitations, a possible lack of estimating experience, and project complexity. As Choi stated in Estimating Prices (2014), many Civil Engineers are trained in design, but lack significant construction experience. As supported by the literature review, an accurate estimate requires that an estimator have applicable construction experience. Given this lack of experience among engineers, and the requirement of experience for a competent estimator, Choi went as far as to pose the following question, “When an engineer prepares an estimate on a construction project, is he or she crossing the line and discipline into an area where he or she has little direct experience or training (P 279)?” While this statement may be considered extreme, it does offer a viewpoint that should be considered. When contractors are required to be responsible bidders, should designers who create Engineer’s Estimates be held to a similar level of responsibility? Further, is it responsible to rely on conceptual and outdated costs compared to others who have extensive and detailed competitive costs?

A more feasible approach is recommended by Harper, Molenaar, Anderson, & Schexnayder in “Synthesis of performance measures for highway cost estimating (2014)”. In this article, the research team states that, if three competitor’s bids are submitted, and all three are above the Engineer’s Estimate, is it the market or the Engineer’s Estimate that is wrong? Harper et al suggests that the current market conditions will represent what the project currently costs. As shown in this study, competition will reduce the cost of the project. DOTs should continue to develop estimates for program funding and rank projects from most needed to least needed. If Winning Bids end up being higher than Engineer’s Estimates, and the program runs out of funding, the most needed projects should continue to be funded, and projects that are least needed should wait for additional funding. Additionally, if Bid Difference is normally distributed, savings on Winning Bids may be used to offset the deficits when Winning Bids exceed the Engineer’s Estimate.

Estimating accuracy has two distinct meanings for contractors and engineers. These two separate meanings
result in two separate outcomes. For the contractor, estimating accuracy means developing a detailed cost approach that will result in the most competitive bid possible. There is no margin of error, and projects must be the lowest responsive and responsible estimate in a pool of competitors to be considered a success. Winning Bids can be lost due to fractions of dollars. Winning Bids should also not be too low, as there could be an indication of errors and omissions made during the estimating process that will result in the loss of profit. An accurate estimate is imperative to a contractor’s success. The costs must be accurate, detailed, and be performed expeditiously so that the estimator may move onto estimating the next project. In contrast, for the engineer, estimating accuracy means developing an Engineer’s Estimate that is ±10% within a Winning Bid. For the engineer, this estimate needs to be approximate, which allows for a significant margin of error when compared to the contractor’s estimating methods. If Winning Bids are higher than anticipated, the designer is allowed the option to re-examine their costs, or re-advertise the project. For the designer, there is no pool of competitors aggressively pursuing a lower bid, as there is with contractors creating a Winning Bid. There is little risk, and less incentive for the designer to create an accurate Engineer’s Estimate.

Most DOTs use a historical-bid based approach. Although this approach may be considered quick and relatively reliable, it may be inaccurate. This lack of accuracy poses problems for the coming years. As the building market recovers and highway funding increases, competition will decrease. During this time, historical costs will no longer be accurate. Engineer’s Estimates will include historical unit prices that do not reflect the market conditions present at the bid time. Without the acknowledgement that these prices are not the same, Winning Bids higher than the Engineer’s Estimate will be submitted. This will cause the award of the project to be delayed, and additional costs to be absorbed by the DOT. Given the unique conditions of the dataset researched in this paper, it is suggested that additional analysis is performed on recent data once it is published and available. Additional analysis will provide the opportunity to determine if the findings in this article are unique to the time period or if they are systematic.

This research does not suggest that the process of developing the Engineer’s Estimate as haphazard, but rather that historically inadequate resources have been devoted to develop an accurate estimate with the required level of detail. The ±10% contingency is included with the acknowledgement of the disparity between the contractor and designer in regards to the level of effort, resources available, and experience. Perhaps this ±10% contingency may not suffice when certain market conditions are present. This issue is magnified in significance when the lesser accurate estimate serves as the basis for contract award or to re-advertise the project.

Our research supported the FHWA’s findings during this research period. Engineer’s Estimates were considered accurate and representative of the market. This success would imply that the methodology of creating an Engineer’s Estimate no longer needs to be improved per the OIG or FHWA recommendations. This is a dangerous assumption. As the linear regressions illustrate, microeconomic variables can significantly impact Bid Difference. These variables can either compensate or forfeit the contingency. During the Great Recession, these market factors compensated the FHWA contingency, and created a cost savings. As the market continues to recover to pre-recession levels, the contingency will be forfeited as historical unit averages may lag up to 4 to 5 years. This will create an increase in Bid Difference, as indicated by the 2012 OIG report. However, these costs will not be presented as a savings, they will be presented as a deficit.

This research presents mixed results that both support and discredit DOTs estimating practices for creating Engineer’s Estimates. The Engineer’s Estimate is relatively accurate in the period researched per the program’s requirements. All three states examined had Bid Difference lower than 10%, and the 2 out of 3 states awarded projects outside of the ±10% range, less than half the time, with one state barely exceeding the 50% program acceptance rate. However, the research supports the theory that microeconomic factors created record low pricing during the Great Recession, which compensated for the lack of accuracy when creating an Engineer’s Estimate. The research identified microeconomic factors that affect Bid Difference. This reduction of Bid Difference justifies the present methodology for developing an Engineer’s Estimate as microeconomic variables have the possibility of decreasing or increasing Bid Difference. Further, the research found that the level of accuracy remains an issue, given that the estimate process for the Engineer’s Estimate is not as detailed as the Winning Bid. The process used to develop an Engineer’s Estimate is inadequate in some cases for...
budgeting for a contract award. Heavy Highway projects are unique; each project has specific requirements and specific conditions that affect pricing. Historical-bid based approaches may not capture these conditions. This issue may be further compounded when microeconomic factors are ignored or unknown at the time of creation of the Engineer’s Estimate.

Data generated or analyzed during the study are available from the corresponding author by request.

REFERENCES


Engineer Estimates [E-mail to R. D. Land]. (2005, September 15).


**ABBREVIATIONS**

CA: California
DOT: Department of Transportation
FHWA: Federal Highway Administration
NC: North Carolina
OH: Ohio
OIG: Office of the Inspector General
SPSS: IBM Statistical Package for the Social Sciences
ABSTRACT

This study examines the usage of design-build by the Department of Transportation (DOT) of the 50 states in the United States. Design-build has been growing in popularity as a procurement form in both the private and public sectors, and in the last ten years many DOTs have started or expanded programs to use design-build for infrastructure projects. However, many DOTs are still struggling to determine the best application of design-build and how to incorporate its use as a procurement method for DOT projects. This study examines how state DOTs are using design-build, when they are using this delivery method, and the processes that the DOTs have established when utilizing design-build. This was accomplished by examining design-build documents that have been published online for each of the 50 state DOTs. It was found that while the large majority of state DOTs are using design-build, only around half of the DOTs have a design-build manual, and only two DOTs have published comparative analyses of design-build projects. The most commonly cited reason for using design-build was its shorter delivery schedule. Also, this study found that most state DOTs complete preliminary design work in-house for design-build projects before going through a two-phase selection process to award a contract.

Key Words: Design-build, State DOTs, procurement methods

Dr. Dennis C. Bausman is a Professor and Endowed Faculty Chair in the Construction Science and Management Department at Clemson University. He is on the Board of Governors for the Constructor Certification Commission and a Certified Professional Constructor.

Dr. Mashrur Chowdhury is the Eugene Douglas Mays Professor of Transportation in the Glenn Department of Civil Engineering at Clemson University. He is the Director of the Center for Connected Multimodal Mobility, a U.S. Department of Transportation (USDOT) Tier 1 University Transportation Center (UTC). He is a Fellow of the American Society of Civil Engineers and Registered Professional Engineer in Ohio.

Christopher Cummings is completing his Bachelor of Science degrees in both Civil Engineering and Economics at Clemson University. His research focuses on transportation systems and analysis.

Sasi Selvam is a Clemson graduate with a Master’s Degree in Construction Science and Management. Sasi has an undergraduate degree in Civil Engineering from Anna University, India.
INTRODUCTION AND LITERATURE REVIEW

The Master-Builder or Design-Builder is not a new concept and has been practiced in various forms and societies for over four millennia. In the 1970’s design-build began to experience a renaissance in the United States as private sector building projects began to look at procurement method alternatives to design-bid-build. However, the use of design-build by the public sector lagged behind the private sector until the 1990s.

Part 36 of the Federal Acquisition Regulation (FAR) governs the contracting for design and construction services by federal agencies and public projects incorporating federal funding. FAR requirements for years had been that no contract for construction could be awarded to the firm that designed the project. However, in the mid-1990s, this was amended to allow the contracting agency for federally funded projects to use a two-phase design/build selection process when certain criteria was met.

The change in Federal Acquisition Regulations for public procurement coupled with the continuing shift toward a qualifications based selection process for project delivery in the private sector has helped fuel the increased use of design-build. In recent years the domestic volume of design-build has increased from $50b in 2010 to approximately $73b in 2015 (Figure 1) reflecting a 45% increase in the use of design-build for project delivery.

What is the design-build method of project delivery? According to the Design Build Institute of America:

“Design-build is a method of project delivery in which one entity – the design-build team – works under a single contract with the project owner to provide design and construction services. One entity, one contract, one unified flow of work from initial concept through completion – thereby re-integrating the roles of designer and constructor. Design-build is an alternative to the traditional design-bid-build project delivery method.” (DBIA Website 2017)

Design-Build and DOTs

Numerous state DOTs have been exploring the use of the design-build procurement method for a variety of needs. The Special Experimental Projects No. 14 – Alternative Contracting (SEP-14) has been an Federal Highway Administration (FHWA) initiative since 1990 to encourage states to explore and develop the use of design-build. Many states have taken advantage of this initiative to introduce and expand design-build for their DOTs.

Since FHWA’s initiative in 1990 all fifty states have authorized the use of design-build as a procurement method for at least some state projects (Figure 2). Some of the states have two decades or more of experience with design-build, while others have begun exploring its application and only recently authorized its use. Currently, over half of the states (26) permit state agencies to use design-build for all types of design and construction and another seventeen (17) states permit the use of design-build on a wide variety of projects (Figure 2). Design build has only limited application in just seven states. It is clear that the design-build delivery method has gained increasing acceptance by state agencies for use on public projects.

Figure 2: A map of the states that currently permit D/B fully or partially (DBIA website).
How Design-Build Procurement Works

For a normal design-build project, an owner will do initial scope development and/or design work before putting the project out for submission of proposals/bids. There are three primary methods for the selection process for a design-build firm: Qualifications-based, Two-Phase best value, and One-Phase best value.

In Qualifications-based the owner will usually solicit a Request for Qualifications (RFQ) from interested firms, and then select a firm from the respondents with the best qualifications to do the work. This approach allows the owner to contract with the design-builder for a project with minimal scope and design defined.

In Two-Phase and One-Phase best value the owner normally initiates scope definition and initial design work in-house. Normally with Two-Phase the owner issues a RFQ to identify a short list of well-qualified design-build firms. This short list of firms is then provided a Request for Proposal (RFP) with the preliminary design work from which they prepare their proposal/bid. The owner then selects a design-builder based upon the criteria established in the RFP. One-Phase is similar to Two-Phase except that there is only one phase of an RFP.

Evaluating Design-Build Outcomes

There have been a number of studies evaluating the impact of design-build on projects utilizing that form of delivery method. These studies used a variety of measures to determine impacts and those measures are summarized here. The studies commonly identified three elements considered important when evaluating project delivery - cost, time and quality. These can be further broken down into specific measuring tools that are ultimately the building blocks of an analysis of a project.

Cost

The cost of the project was examined most commonly through either total cost of the project or unit cost of the project (Purdue 2009, Chan 2004, DBIA 2017, FHWA 2006, Konchar 1997, Molenaar 1999, Hale 2005, Wardani 2006, Lam 2008, Rosner 2009). By using unit cost of the project, studies were able to control for variations in project size. Cost growth was also used commonly in addition to either total cost or unit cost. Cost growth is a measure of how over/under budget a project was at its completion (Molenaar 1999, DBIA 2017, FHWA 2006, Konchar 1997, Hale 2005, Allen 2001, Rowlinson 1988, Wardani 2006). Change order rate and change order cost added were two measures used by several studies to examine whether design-build projects were more susceptible to change orders (Purdue 2009, McGraw-Hill 2014, Molenaar 2003, Rosner 2009).

Time

There were only a few measures of time that were common among nearly all of the studies. Total time of the project, including both design and construction time, was fairly typical (Purdue 1999, Chan 2004, Hale 2005, Allen 2001, Lam 2008). Since total time does not account for the size of the project, a number of studies also used measures of design speed and construction speed in determining if design-build projects were faster than other forms of procurement (DBIA 2017, FHWA 2006, Konchar 1997, Rowlinson 1988, Wardani 2006). Schedule growth was often used as a measure of how far ahead or behind schedule a project was at completion (Molenaar 1999, DBIA 2017, FHWA 2006, Konchar 1997, Hale 2005, Allen 2001, Rowlinson 1988, Wardani 2006, Rosner 2009).

Quality

Whereas measuring cost and time can be relatively straightforward, quality is a much more subjective element and therefore more difficult to measure. A number of studies have attempted to measure the impact that D-B has on project quality, but often the analyses simply steered clear of any attempt to measure this subjective component. Among those studies that analyzed quality, it was most commonly done by distributing surveys to project owners, designers, contractors and/or users (Molenaar 1999, Chan 2004, McGraw-Hill 2014, FHWA 2006, Molenaar 2003, Allen 2001, Lam 2008). These surveys usually asked for the party to rate on a numerical scale factors such as user satisfaction with the final product, conformity to specifications, conformity to expectations, quality of the construction process and the overall quality of the project. While these are not empirical measures, they do provide perceived
The representation of the quality of a project which can then be incorporated into the analysis of the delivery method.

**Impacts of Design-Build compared to Design-Bid-Build Projects**

Using the previously described measures many studies have evaluated the impact of design-build as a project delivery method. The analysis often compared design-build to traditional design-bid-build projects. The most significant impact of design-build on highway projects was noted to be a decrease in total project time (FHWA 2006, Shrestha 2012, McGraw-Hill 2014, Molenaar 2003, FDOT). This conclusion of time savings was echoed in other studies of the design-build process for buildings (Hale 2005, Allen 2001). The impact of design-build on project cost was more ambiguous, but most major studies concluded that there was no significant difference regarding cost (FHWA 2006, Shrestha 2012, McGraw-Hill 2014, Hale 2005). It was also found that design-build showed no significant difference in quality (FHWA 2006). In addition, several studies also concluded that design-build had less schedule and cost growth than design-bid-build (Molenaar 1999, Molenaar 2003, FDOT, Hale 2005). Based on the collective findings in these past studies, the use of design-build resulted in a shorter period for project delivery without an increase in cost or reduction in quality. These findings support the increased use of design-build by both private and public owners.

**STUDY OBJECTIVES AND METHODOLOGY**

**Study Objectives**

The primary goals of this study were to determine: 1) the extent to which design-build is utilized by state DOTs for project delivery, and 2) the design-build procurement process utilized by state DOTs. The specific objectives of the study were:

- To identify the number of D/B projects that are active for each state DOT
- To identify the reasons or circumstances influencing the use of D/B on state DOT projects
- To identify which state DOTs have a design-build (D/B) manual
- To determine the design-build procurement process used by state DOTs
- To determine at what point in the design-build process DOTs contract with the D/B firm
- To determine how many state DOTs provide stipends for D/B proposals
- To determine the type(s) of D/B contract used by DOTs

**Methodology**

Researchers conducted document analysis for this research. To find information relative to the study’s objectives, the researchers did a review of available design-build documents on the website of each of the fifty state DOTs. The available documents usually included a mixture of design-build manuals, guidelines, RFQs and RFPs. Additionally many state DOTs published lists of active and completed design-build projects. The timeframe for this analysis was approximately two months to complete an analysis of all fifty state DOTs, with approximately two hours spent reviewing the documents from each DOT.

The researchers began each state DOT design-build analysis on the DOT website. The researchers first located any available lists of active design-build projects for the state DOT. When these lists were available, the number of active projects were counted and recorded. The researchers then located any available design-build manual for the state DOT on the website. The design-build manuals often contained most of the information needed to address the study objectives. In particular, the D/B manuals typically contained a thorough review of the design-build procurement process. A document was considered to be a design-build manual if it: 1) outlined a procurement process specifically for design-build, 2) provided a detailed process for project scope development prior to contracting, 3) provided a detailed accounting of the process for the RFQ and/or RFP, and 4) detailed how a D/B firm was selected and contract awarded. If the state DOT had a manual then the manual was reviewed and available study objective information was recorded. If the state DOT did not have a manual, then the research team examined other resources available on the DOT website. The researchers located other available design-build documents such as guidelines, RFPs and RFQs. These design-build documents were reviewed to retrieve data necessary to address the Study Objectives. The process utilized is summarized in Figure 4.

**Findings**

**Prevalence of Design-Build and Circumstances for Use:**

From the study it can be determined that the prevalence of design-build among state DOTs varies widely. Forty-
six states allow design-build, while four states have not legally approved the state DOT to use design-build. There are at least thirteen states, including Tennessee and Louisiana that have only been using design-build on an experimental basis for a handful of projects (fewer than ten). Other states have used design-build much more extensively. The researchers found evidence that nine or more states had in progress at least one dozen design-build projects. And at least four states, (New York, Ohio, Virginia and Florida) had more than 25 active design-build projects (Figure 5).

Figure 4: Flow chart of the process used to complete the study objectives.

There are also a variety of reasons and objectives that state DOTs have for using design-build for project delivery. Twenty-nine states provided input and the distribution of their reasons for using D/B are provided by the graph shown in Figure 6.

As is shown in Figure 6, the most common circumstance for the use of design-build was for projects that required a shorter delivery schedule. This study found that 93% of the state DOTs (27 of the 29) utilized design-build to more quickly deliver the project. It should be noted that this category includes emergency projects. Four states specifically separated the circumstances of emergency projects and shorter delivery schedules, but other states appeared to combine emergency projects within projects requiring a shorter delivery schedule. Therefore the researchers decided to combine these overlapping circumstances.

Complex projects and projects with the possibility of innovation were listed as reasons for the use of D/B for 45% and 48% of the state DOTs respectively. Other circumstances listed by state DOTs included 28% identifying potential cost-savings with design-build, 24% indicated that they used D/B on projects with a well-defined scope, 21% indicated that they thought D/B provided a better distribution of risk, and 10% said that design-build allowed for greater cost certainty.

Figure 5: Number of DOTs with each number of active projects

Figure 6: Reasons for Using Design-Build
The finding that 28% (8 of 29) of state DOTs thought that design-build provided the opportunity for potential cost-savings is in contrast to the findings of earlier studies noted in the Introduction section of this paper. During the research team’s literature review it was found that most major studies of design-build projects on large transportation infrastructure projects (FHWA 2006, Shrestha 2012, McGraw-Hill 2014, Hale 2005) found no significant cost savings for the use of design-build compared to design-bid-build. This reveals a disconnect between the research findings regarding design-build and the impression that state DOTs have of the effect that design-build has on project cost. Earlier studies support the supposition that the use of design-build does not reduce cost, but can have positive influence on the certainty of the final cost of the project. Design-build has been shown by at least four prior studies to yield less cost growth (Molenaar 1999, Molenaar 2003, Hale 2005). However, only 10% of state DOTs listed greater cost certainty as a reason for using design-build.

**Design-Build Manuals**

It was found that 46% of state DOTs (23 of 50) have design-build manuals, handbooks, or guidelines extensive and thorough enough to be considered a design-build manual (for the criteria used to determine a design-build manual, see the methodology section). Thirteen (26%) DOTs did not have sufficient documentation to be considered a design-build manual, but they had published limited guidelines, checklists for design-build, and/or sample RFQs or RFPs. Twenty percent of the DOTs did not have any published design-build documents on their website, and 8% (4 state DOTs) do not currently allow the design-build method to be used by the state DOT. See Figure 7 for a summary of these findings.

Nearly all manuals and guidance documents reviewed were primarily concerned with the design-build procurement process, including outlining and detailing the development of RFQs and RFPs, the creation and operation of selection committees, and the bidding process. Several manuals also outlined different options for contracts and bidding processes. Examples of extensive manuals for the procurement process include the manuals for the DOTs of California, Michigan and Florida. The length of the documentation for all the DOTs varied widely from as few as six pages for limited guidance documents to full design-build manuals that exceeded 200 pages in length. However, most of the manuals ranged between 30 and 100 pages in length.

The researchers found that 30% of the state DOTs with a manual (seven of the twenty-three) included sections about the administration of design-build contracts in addition to the procurement process. State DOTs that did not address contract administration in their manuals generally indicated that contract administration under design-build was the same as, or very similar to, administration under traditional design-bid-build. Two examples of a thorough definition of the administration of design-build projects were found in the design-build manuals for the Pennsylvania and Arizona DOTs.

**State DOT Design-Build Studies**

Among the forty-six states currently using design-build, only two have completed studies and published findings on their website comparing completed design-build projects with design-bid-build projects. The two states are the Florida DOT and the Washington State DOT.

The Florida DOT (FDOT) study examined two projects performing a similar scope of work that started at the same time. One used design-build and the other used design-bid-build. The study examined the cost and time for the design, selection, and inspection as well as cost and time overruns. The results of the study are summarized in Table 1 below.

<table>
<thead>
<tr>
<th></th>
<th>Design-Build</th>
<th>Design-Bid-Build</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cost (millions of $)</td>
<td>$62.5</td>
<td>$68.9</td>
</tr>
<tr>
<td>Total Time (days)</td>
<td>1,466</td>
<td>2,122</td>
</tr>
<tr>
<td>Cost Overrun (%)</td>
<td>1.98 %</td>
<td>4.33 %</td>
</tr>
<tr>
<td>Time Overrun (%)</td>
<td>20.3 %</td>
<td>19.7 %</td>
</tr>
</tbody>
</table>

*Table 1: Results from FDOT study comparing D/B and D/B/B.*

The Washington State DOT (WSDOT) published a similar study of a design-build project, except in their study the
final project numbers of the design-build project were compared to estimates prepared by an engineer of what the outcomes for the project would have been using design-bid-build. This study examined project cost, time, and quality, the key findings are shown in Table 2.

<table>
<thead>
<tr>
<th>WSDOT</th>
<th>Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cost</td>
<td>23% MORE expensive</td>
</tr>
<tr>
<td>Cost Growth</td>
<td>1% for entire project, LOWER than expected</td>
</tr>
<tr>
<td>Total Time</td>
<td>16% FASTER</td>
</tr>
<tr>
<td>Quality</td>
<td>“Quality was EQUAL or BETTER…”</td>
</tr>
</tbody>
</table>

Table 2: Key results from WSDOT study comparing D/B to estimated D/B/B projects.

The results found were generally in line with the results found in the studies outlined in the literature review. Several major studies of the use of design-build on highway projects, such as FHWA’s 2006 study, found that there was no significant cost difference between design-build and design-bid-build. However, the cost findings of these two studies were mixed with FDOT concluding a lower cost for design-build, while WSDOT found a much higher cost for design-build. Nearly all of the prior studies had found time savings for design-build, and both FDOT and WSDOT found a significant reduction in project time as well. Lastly, several prior studies found lower cost growth for design-build (Molenaar 1999, Molenaar 2003, Hale 2005), which was in line with the findings of both FDOT and WSDOT.

Leaders in the use of Design-Build

There are a variety of state DOTs which have developed thorough design-build manuals. This section identifies three of the state DOTs that have developed both thorough manuals for design-build and have extensively implemented the use of design-build for DOT projects in order to make note of what a more expansive use of design-build can look like for state DOTs.

Virginia DOT has developed an extensive design-build manual that was last revised in 2011. This manual guides users through the procurement phase of design-build from the decision to use design-build up to the award of a contract by defining the steps of the process and how each step should be carried out. Virginia DOT currently has 25 active design-build projects statewide, which is a relatively high number compared to other state DOTs. The DOT uses design-build for emergency projects and shorter delivery schedules, projects with higher complexity and those with possible cost-savings if D/B is utilized. In practice design-build has been implemented on bridge replacements, highway widenings and extensions, interchange improvements and traffic and safety management systems.

Another leader in the use of design-build has been Florida DOT. The Florida DOT design-build manual was last revised in 2015 and provides an extensive overview of the procurement of design-build contracts by thoroughly defining each element of the process and what responsibilities the DOT has at each point. In Florida there are 33 active design-build projects, which is also a comparatively high number. Design-build is used for projects with shorter delivery schedules, required right-of-way acquisition and/or utility relocation, well-defined scopes, and projects with the potential for innovation. Florida DOT has used design-build contracts for various projects and commonly utilizes D/B for bridge construction and replacement, maintenance projects, and pavement projects on highways.

Ohio DOT has been very active in its use of design-build for transportation projects, with 57 approved projects in 2016 alone. Ohio is one of the highest users of design-build among state DOTs. The state has identified several circumstances that pose good project choices for design-build. These include a well-defined project scope, a shorter delivery schedule, and the possibility of innovation on the project. They have used the design-build method for numerous types of projects including bridge replacements and repair, culvert and guardrail projects, resurfacing, interchanges, road rehabilitation, widenings, noise walls and signage. In addition to Virginia and Florida, Ohio shows the broad potential for application of design-build by state DOTs.

Bidding Process

This study investigated several key parts of the bidding process for design-build projects in use by state DOTs including: a) the point at which the design goes to contract, b) the use of stipends for unsuccessful bidders, c) one-phase versus two-phase bidding, and d) the type of contract implemented.

The researchers found that 68% of state DOTs (34) defined the level to which they completed the initial design work for a design-build project. All 34 DOTs indicated that the contracting phase is done after the development of the project scope, specifications, and the conceptual documents that contain the preliminary design requirements. Other aspects of the preliminary design that DOTs developed before contracting included acquiring the right-of-way, geotechnical analysis and environmental permits. Ten (10) state DOTs identified the percentage of design work done before contracting. All estimated it to be close to 30% of the design work, with 20% being the lowest percentage and 35% the highest.
Stipends were paid to the firms that unsuccessfully bid on an RFP contract to compensate for the design cost involved in developing a proposal and to encourage a greater number of competitive proposals. Among the 50 state DOTs studied, 68% (34 DOTs) use stipends for design-build for all or some projects. This figure represented 97% of DOTs that defined a policy on stipends. Those that did not use universal stipends typically left their use up to the discretion of the oversight committee or project manager. Only 2% (one DOT) was found to not use any stipends for design-build work, while 30% (15 DOTs) did not define whether or not they used stipends (Figure 8).

Figure 8: Use of Stipends by State DOTs

Contracts were awarded by most DOTs on the basis of an adjusted low-bid process. This process had several DOT engineers evaluate and rate each bid’s technical proposal, and this rating was combined with the total cost of the bid using a formula to arrive at the lowest ‘adjusted’ cost for the project. All 34 state DOTs that defined their awarded contract type in their design-build manual or other documents said they use a lump sum contract. There were instances of DOTs having documents that allowed for the contract type to change based on the circumstances of each project, and it was noted that state DOTs would sometimes deviate from their own guidelines and use other contracting types.

CONCLUSION

This study has examined the extent of the usage of design-build and the overall approach of the design-build procurement process among state DOTs. It was determined that design-build has been approved for use by 92% of state DOTs (46 out of 50). However, only 46% (23) of state DOTs have full design-build manuals for the selection, development and procurement process for D/B projects. Furthermore only two state DOTs (Florida and Washington) have published an analysis of D/B projects comparing design-build with other delivery methods. The level of usage of design-build by each state DOT varied widely from less than a half dozen projects ever awarded up to several dozen design-build projects awarded each year. The most common circumstance for using design-build was for projects with a shorter delivery schedule (including emergency projects).

Among the state DOTs using D/B, the majority (55%) of DOTs used a Two-Phase procurement process, consisting of an RFQ phase used to create a shortlist of bidders followed by an RFP that involves detailed project proposals. Eleven percent (4 states) used only Single-Phase bidding, which only involves an RFP step. Thirty-four percent (13 states) used both Single and Two-Phase bidding for design-build, depending on the circumstances of the project (Figure 9). Some of the state DOTs stipulated that with their Single-Phase process they only accepted bids from pre-qualified contractors or firms the DOT had worked with before. This pre-qualification can be seen as similar in purpose to an RFQ step, which then creates some overlap between the use of Single and Two-Phase bidding.

Contracts were awarded by most DOTs on the basis of an adjusted low-bid process. This process had several DOT engineers evaluate and rate each bid’s technical proposal, and this rating was combined with the total cost of the bid using a formula to arrive at the lowest ‘adjusted’ cost for the project. All 34 state DOTs that defined their awarded contract type in their design-build manual or other documents said they use a lump sum contract. There were instances of DOTs having documents that allowed for the contract type to change based on the circumstances of each project, and it was noted that state DOTs would sometimes deviate from their own guidelines and use other contracting types.

CONCLUSION

This study has examined the extent of the usage of design-build and the overall approach of the design-build procurement process among state DOTs. It was determined that design-build has been approved for use by 92% of state DOTs (46 out of 50). However, only 46% (23) of state DOTs have full design-build manuals for the selection, development and procurement process for D/B projects. Furthermore only two state DOTs (Florida and Washington) have published an analysis of D/B projects comparing design-build with other delivery methods. The level of usage of design-build by each state DOT varied widely from less than a half dozen projects ever awarded up to several dozen design-build projects awarded each year. The most common circumstance for using design-build was for projects with a shorter delivery schedule (including emergency projects).
state DOTs are awarding stipends to unsuccessful D/B bidders to help bidders recover the cost of the design work involved in developing a proposal. It was determined that the state DOTs typically do about 30% of the design work for D/B projects in-house before going to contract, and this design work involves preliminary design work, ROW acquisition, geotechnical analyses and environmental permits. All thirty-four state DOTs that defined the contract type for D/B projects said they use lump sum contracts, however it was noted that the DOTs would sometimes deviate and use other forms of contracts.

This study provided insight regarding the use of Design-Build by DOTs across the nation. The findings of the research effort provide an understanding of the present use and application of the Design-Build delivery method by state DOTs. The findings also highlight the wide disparity of adoption and approach implemented across the country which reinforces the need for additional study to identify the optimal use and application of this delivery method for DOT projects.

REFERENCES


FDOT. “Design-Build and Design-Bid Build: Comparison of Overall Cost and Time.” Florida Department of Transportation.


Construction Disputes in the United States and the United Kingdom: A Comparison

Anusree Saseendran, Arizona State | asaseend@asu.edu
Ben F. Bigelow, University of Oklahoma
Zofia Rybkowski and Dawn Jourdan, Texas A&M University

ABSTRACT

Construction disputes are on the rise globally. They adversely affect the progress and quality of a construction project by resulting in cost overruns and delays. They are also time-consuming and expensive to resolve. Hence it is valuable to identify the most disputed topics in construction in the US and compare them to those in a different country. This helps better understand disputes, and the influence that culture and the difference in the nature of construction in the regions may have on disputes. This study was an attempt to identify and compare the most disputed topics in construction in the United States and the United Kingdom. It represents the first empirical attempt to quantify construction disputes with regards to the topic areas of disputes. This study used an exploratory qualitative method of inquiry based on the perceptions of attorneys practicing construction law to identify the most disputed topics in construction. The findings of the study revealed that the four most disputed areas are the same in both countries - delay, defects, changes and payment, indicating their pervasiveness.

Keywords: Construction Disputes, Most Disputed Topics, Comparison of US and UK

Anusree Saseendran is a doctoral student in Construction Management at Arizona State University. Her research interests include organizational behavior, risk maturity, and the impact of human dimension on performance.

Dr. Ben F. Bigelow is an Associate Professor at the University of Oklahoma. He serves as the Director of Haskell & Irene Lemon Construction Science Division in the university.

Dr. Zofia Rybkowski is an Associate Professor in the Department of Construction Science at Texas A&M University. She is a holder of the Harold Adams Interdisciplinary Professorship in Construction Science.

Dr. Dawn Jourdan is a Professor in the Department of Landscape Architecture & Urban Planning at Texas A&M University. She also serves as the Executive Associate Dean in the College of Architecture in the university.
INTRODUCTION

Disputes in construction are commonplace and recurrent. They can occur between any of the parties in a construction contract – owner, designers and contractors. They often result in cost overruns and delays in project delivery, and can adversely affect the quality of the project. There exists a multitude of definitions as to what a dispute is in the academic literature. Hence, it is necessary to define dispute first. A dispute is “any contract question or controversy that must be settled beyond the jobsite management” (Diekmann, Girard & Abdul-Haidi, 1994). Rule 1 of the Institution of Civil Engineers (ICE) Arbitration Procedure states that a dispute or difference shall be deemed to arise “when a claim or assertion made by one party is rejected by the other party and that rejection is not accepted” (Eggleston 1993). Disputes in construction can be attributed to the conflicting interest of the large number of participants.

Number of Disputes

National Building Specification (NBS) in the UK has been administering the National Construction Contracts and Law survey every two years since 2013 to obtain information about disputes in the construction industry. The 2013 survey found that with 30% of the respondents had entered into a dispute within the past year, which was an increase of 6% from the previous year (NBS, 2013). The Construction Contracts and Law Survey administered by NBS in 2015 (NBS, 2015) reported that only 8% of the respondents reported the number of disputes in construction to have decreased in 2011, 10% in 2012 and 9% in 2015. In all three years, the majority indicated that the number of disputes in the construction industry has either remained the same or has increased as compared the previous year. The 2013 survey found that the client and the main contractor were in dispute 76% of the time. The study also established that disputes generally involve large sums of money and significantly affect the construction process. It found that 35% of the disputes reported had an approximate value between £250,000 ($356,000) to £5 million ($7 million), and nearly 20% of the disputes had a reported value in excess of £5 million ($7 million).

Length and Value of Disputes

Studies have also found a marked increase in both the value and the length of disputes from 2013 to 2014 globally (Arcadis, 2015). The findings of the Global Construction Dispute Reports (Arcadis, 2015) state that the value of disputes have increased considerably from 2013 to 2014 in Continental Europe (39.3%), the Middle East (87.5%), and Asia (104.3%), while it dipped marginally in the United Kingdom (3.2%) and the United States (13.7%). In spite of the drop in dispute values in the United States and the United Kingdom, both these countries saw an increase in the time it took to resolve disputes. The length of disputes increased by 18.2% in the United States, averaging around 16.2 months, while it increased by 26.6% in the United Kingdom, averaging around 10 months to resolve. Thus, once a dispute arises, it can be laborious and expensive to resolve. In this regard, it is crucial to understand the most disputed topics in construction.

The Most Disputed Topics in Construction

The main issues disputed in the United Kingdom in 2013 were identified to be extension of time, valuation of final contract, valuation of variations, loss and expense, and defective work (NBS, 2013). However, information comparable to this was not available in the United States based on the researchers’ literature searches. Some law reviews make unfounded claims about the most disputed issues in construction to support an argument; however these claims are often not supported by empirical study. For instance, Spurr (2009) speculates that the most common disputes in construction in the United States are related to non-payment, followed by disputes as to what is owed by the owner and what should have been built by the contractor, and what was intended to be shown in plans and specifications by way of detail. Bridston (2009) ventures that delay and impact claims are the most common, followed by limitation of liability clauses. The most common claims identified by Ledet (2014) are defect, delay, constructive acceleration, scope change, force majeure, differing site conditions, and performance failure claims. However, according to Hughes (2012), the number of delay claims and scope of work issues are seeing a sharp decrease nationally. These claims as to the most disputed clauses in the United States, not only contradict each other at times, they are also anecdotal at best, since they are not supported by empirical evidence.

Only a very limited amount of information could be found regarding the most disputed construction topics in the United States. Searches for literature were made at the library of Texas A&M University, with the help of the government librarian, as well at the Law Library at the university, with the help of the research librarian. When these searches netted no empirical study of this
nature, National Building Specifications was contacted to ascertain whether a study similar to National Construction Contracts and Law Survey, which identified the main issues in dispute in the United Kingdom in 2015, existed in the U.S. When this avenue also came up empty, WestlawNext, was searched and identified a few law reviews that discussed dispute resolution methods and changing trends in construction law. However, because law reviews require no empirical evidence or methodology they represent little more than anecdotal evidence.

This study addresses this gap in the body of knowledge on disputes in construction, by identifying the most disputed construction topics in the United States and comparing them to those in a different country. The United Kingdom was selected as the other country in this study based on convenience. In addition, while U.K. is culturally similar to the U.S., the same cannot be said for the nature of construction in the two countries in terms of project delivery systems, contracting mechanisms, technology adoption, and drivers of construction, thereby providing a deeper context on construction disputes to draw conclusions from.

This study sought to identify and compare the most disputed topics in construction in the United States and the United Kingdom. Specifically, the research questions of this study were 1) Which stakeholder initiates the most disputes in construction in the United States and the United Kingdom? 2) What are the most disputed topics in construction in the United States and the United Kingdom? 3) How do the most disputed topics in these countries compare to each other?

This study is needed as it represents the first empirical attempt to quantify construction disputes. While amounts of disputes have been studied, the topic areas of disputes have not been the subject of empirical study. The significance of this study comes by identifying the most disputed topics in construction in these two countries, thereby identifying problem areas in construction that should be of increased importance to project stakeholders. This can, in turn, help reduce disputes thereby improving the construction process and potentially reducing costs via reduced litigation.

**METHODOLOGY**

This research represents an exploratory study to evaluate common disputes in the construction industry, based on the perceptions of attorneys practicing construction law. Qualitative research uses an open and flexible design, and the researcher plays as much a part of the research process as the participants and the data they provide (Corbin & Strauss, 2014). The qualitative strategy that was used for this study is grounded theory. This strategy is used when the researcher needs to derive a theory of a process, action, or interaction which is grounded in the views of participants (Cresswell, 2007).

In the absence of any empirical study and thus data on the most disputed topics in construction, an online survey was created to identify these topics and the stakeholder who initiate the most disputes. Although it was attempted to disseminate the survey via the Construction Law Section of the State Bar of Texas, and the Society of Construction Law (SLC) in the United Kingdom neither group would share their member’s email addresses. As a result, the researchers employed a snowball sampling technique to collect data. Snowball sampling is a nonprobability sampling technique where existing study subjects recruit future subjects from among their acquaintances, and the future subjects recruit further subjects and so on. This method is considered appropriate when it is difficult to locate people of a specific population (Biernacki & Waldorf, 1981; Goodman, 1961).

For this study, attorneys known to practice construction law were sent the survey directly and asked to forward it to their colleagues practicing construction law as well. While a response rate could be inferred based on the number of individuals the surveys were sent to, the total number of individuals who received the survey is unknown because of the use of snowball sampling. 59 responses were collected from construction lawyers based in the United States, primarily in the Texas region. From the United Kingdom, 35 responses were collected from lawyers based in London.

The survey consisted of eight questions and can be found in the appendix of this paper. The questions sought to understand the respondents’ experience in the construction industry, the scale of disputes they have been involved in, and their familiarity with different contract forms. At the end, the survey asked the respondent to list the five most common construction-related disputes and were asked whether the disputes were associated with a particular contract type.

The most disputed issues in construction in the United States were identified using coding (Cresswell, 2007; Strauss & Corbin, 1990). The first step is called open
coding, where the data collected was broken down, examined, compared, and categorized. Next axial coding was done by putting data back together by making connections between categories. Lastly, selective coding was done by identifying the core category(s). After coding, to address the threat of bias to the analysis and improve reliability, another researcher (who was not involved in the initial coding process) coded the data to ensure identified themes emerged from the data and not the researcher. This process produced good consistency indicating the analysis had good interrater reliability. Additionally triangulation through the literature review was used to give credibility to the methods used in this study (Creswell, 2007).

In summation, this exploratory study involved surveys, coding and thematic analysis, to identify and compare the most disputed clauses in the United States and the United Kingdom. Descriptive statistics were then used to show comparisons between the themes.

RESULTS AND DISCUSSION

From the responses collected, it was found that 88% of the respondents in the United States were familiar with AIA or ConsensusDOCS, as compared to 97% of the respondents in the United Kingdom who were familiar with either Joint Contracts Tribunal (JCT) contracts or National Engineering Contract’s (NEC) Engineering and Construction Contracts (Figure 1), potentially indicating a higher use of custom contracts in the US as compared to the UK.

As shown in Figure 2, the respondents in both regions represented owners and general contractors more than subcontractors on average, however the representation of project owners among the respondents was higher in the U.K. (55%) than in the U.S. (34%).

![Figure 2. Representation by Stakeholder](image)

The vast majority of the US respondents’ construction-related practice is devoted to the commercial sector (57%), as compared to residential (15%), industrial (17%) and infrastructure (11%) sectors. Similarly, most of the construction-related portions of the UK respondents’ practice is devoted to commercial (31%) construction, followed by infrastructure (28%), residential (24%) and industrial (16%) construction, see Table 1.

<table>
<thead>
<tr>
<th>Industry Segment</th>
<th>U.S.</th>
<th>U.K.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>57%</td>
<td>31%</td>
</tr>
<tr>
<td>Residential</td>
<td>15%</td>
<td>24%</td>
</tr>
<tr>
<td>Industrial</td>
<td>17%</td>
<td>16%</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>11%</td>
<td>28%</td>
</tr>
</tbody>
</table>

The respondents felt that most of the construction disputes in the US were initiated by project owners (38%), that general contractors and subcontractors initiated disputes almost equally (30%), while 2% of the respondents denoted ‘others’ as the initiator of disputes, and elaborated further by listing suppliers, surety, architect/engineer, and second tier subcontractors. However, general contractors were identified to be the major initiators of disputes (50%) in the UK, followed by project owners (26%), subcontractors (22%), and other stakeholders (2%), see Table 2. The other stakeholders who were identified were end users and professional consultants such as architects. The survey did not collect
information about who the stakeholders were initiating the disputes against.

### Table 2. Initiators of Disputes

<table>
<thead>
<tr>
<th>Initiator</th>
<th>U.S.</th>
<th>U.K.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Owner</td>
<td>38%</td>
<td>26%</td>
</tr>
<tr>
<td>General Contractor</td>
<td>30%</td>
<td>50%</td>
</tr>
<tr>
<td>Subcontractors</td>
<td>30%</td>
<td>22%</td>
</tr>
<tr>
<td>Others</td>
<td>2%</td>
<td>2%</td>
</tr>
</tbody>
</table>

The difference in stakeholder initiation of disputes in the two countries may be arising from the fact that the most disappointed person complains. In this case, the authors speculate that contractors in the US, and owners in the UK do not get what they expect from construction contracts, possibly because they did not set out their expectations clearly enough in the contract. However, this could also be the result of contracts that favor one party over the other in each country. This study did not explore these avenues fully during data collection, and therefore they warrant a closer inspection in the future.

On average, the respondents in the US reported that only 3% of the actual amounts in controversy for construction disputes was less than $10,000 or higher than $10 million. A majority of the respondents (58%) reported that the disputed amount was between $10,000 and $500,000. However, in the UK, more than half the respondents (63%) reported that the actual amounts in controversy for construction disputes was above $500,000, and only 4% reported the value to be less than $10,000. This is shown in Table 3. The authors speculate that the disputed amounts in construction may be correlated to the size of the firm that the respondents belong to. However, it is not possible to make these correlations at this stage because the survey did not enquire about the respondents’ firm size.

As shown in figures 3 and 4, the respondents reported that 59% of the construction projects are governed by AIA contracts, followed by custom contracts (27%), other contract forms (7%) and ConsensusDOCS (4%). Other contract forms identified were DBIA, government forms, agency, and modified AIA contracts. One of the respondents clarified that most commercial projects use AIA contracts, municipality utility work use city forms and that most industrial forms are custom. In the United Kingdom, 55% of the respondents reported to using JCT contract forms most frequently, followed by other contracts (17%), NEC (16%) and custom contracts (11%). Some of the other contracts reported were the International Federation of Consulting Engineers Contract (FIDIC), ICE, Project Partnering Contract (PPC), Term Partnering Contract (TPC), and IChemE. It is of interest to note that the most widely used standard contract forms in both countries – AIA and JCT, are backed by the countries’ respective architectural bodies. On the other hand, ConsensusDOCS and NEC, which are not as widely used, are fairly recent in their origins and were published by improving upon existing standard forms.

### Table 3. Disputed Amounts in Construction

<table>
<thead>
<tr>
<th>Amount</th>
<th>U.S.</th>
<th>U.K.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than $10,000</td>
<td>3%</td>
<td>4%</td>
</tr>
<tr>
<td>$10,000 - $100,000</td>
<td>29%</td>
<td>17%</td>
</tr>
<tr>
<td>$100,000 - $500,000</td>
<td>29%</td>
<td>16%</td>
</tr>
<tr>
<td>$500,000 - $1,000,000</td>
<td>19%</td>
<td>20%</td>
</tr>
<tr>
<td>$1,000,000 - $10,000,000</td>
<td>17%</td>
<td>22%</td>
</tr>
<tr>
<td>More than $10,000,000</td>
<td>3%</td>
<td>21%</td>
</tr>
</tbody>
</table>

Figure 3. Predominance of Construction Contract Forms in the United States

From the survey responses, delay was identified as the most disputed topic in the construction industry in the United States and the United Kingdom. Compared to 69% of the respondents in the US, 94% of the UK respondents listed delay as the most common construction-related dispute. Delay was selected as the core category among others such as scheduling, timeliness of work, phasing claims, and weather impacts. The next most disputed topic that was identified was construction defects in the US and defects in the UK (68% and 74% of the respondents in the US and the UK respectively). Other related categories to construction defects were poor workmanship, nonconforming work, latent defects, and quality of
work. 61% of the respondents in the US and 71% of the respondents in the UK identified change as a commonly disputed issue, making it the third most disputed area in construction in both regions. Other related categories that were listed were extra work and scope inaccuracies. The next most disputed issues in construction in both countries is payment, which was identified by 40% of the respondents in the US and 66% of the respondents in the UK. Other categories related to these were fee, cost overruns, pay-when-paid, subcontractor payment, and lien/bond claims. There was a divergence in the fifth most disputed area in construction in both the countries. It was identified to be design defects in the US (24%), with defective engineering as other category, while it was termination in the UK (20%), with insolvency as a related category. Figure 5 illustrates the most disputed issues in both countries, and displays the consistency of the claims in both countries.

CONCLUSIONS

Construction disputes transcend geographical boundaries and are a global issue in construction, to the extent that they are considered as an occupational hazard within the construction industry. They adversely affect the progress and quality of construction worldwide, which necessitates shifting the focus from making disputes easier to resolve through dispute resolution methods to preventing them in the first place. Towards this end, this study identified the top five most disputed topics in construction in two countries and compared them to explore the problem areas in each country. The findings lend credence to the claims of Bridston (2009), Spurr (2009), and Ledet (2014) – all disputed areas that were identified in this study have been reported in these law reviews as the most commonly disputed. Both Bridston and Ledet list delay, which has been found to be the most disputed topic in this study, as a problem area. Defect, listed by Spurr (2009) and Ledet (2014) as a common construction claim, was found to be the second most disputed topic in construction. This study also found that change, identified by Ledet (2014), and payment, identified by Spurr (2014), were the third and the fourth most disputed topics in construction respectively. These claims were previously unfounded since they were not supported by empirical research.

Of interesting note is the fact that according to Bigelow, Bilbo, and Baker (2016) the highest research priority of general contractors is productivity and scheduling, which closely aligns with the most disputed topic identified here of delay. This correlation suggests that general contractors are already tuned into this problem and are interested in solutions, but have yet to find them.

This study revealed that the top four disputed areas were the same in both countries – delay, defects, change and payment. This suggests that despite contractual and cultural differences these issues could be considered
inherent to construction. The universality and ubiquity of these particular topics within the construction sector warrant attention not only while drafting a contract or revising a standard contract form, but while negotiating the contract terms before commencement of a project as well. Beyond initial contract execution they represent topic areas where project management should exercise greater diligence to avoid disputes later.

In conclusion, this study identified four pervasive issues in construction among the respondents in two countries on both sides of the Atlantic. However this study only considered disputes that go to litigation and not those that are resolved through alternative dispute resolution mechanisms. Since the findings are based on perceptions, their generalizability is limited. Nevertheless, in the absence of empirical research in this area, this study took a first pass at identifying and comparing disputed areas in construction in the two countries. It is necessary to continue this research, and for future research, the author recommends the following topics: 1) The differences in contract interpretation in the US and the UK with respect to originalism, textualism, intentionalism, and pragmatism; 2) Focused research to explore what specifically leads to the disparity in the initiation of disputes by stakeholder in the US and the UK; 3) Comparison of contractual provisions to identify the disparity in the fifth most disputed area in both regions (design defects and termination), 4) Identification of disputed areas by market sectors, 5) Data collection in other countries to explore common disputes in other countries, and 6) Exploring the causes of the most commonly disputed topics in construction.

Appendix: Survey Questionnaire (US)

Please take a few minutes to fill out this survey on disputes in construction.

Q1 Are you familiar with either of the standard form contracts set up by American Institute of Architects (AIA) or ConsensusDOCS?
Yes
No

Q2 In the construction-related portion of your practice, what percentage (%) is devoted to representation of:
Project owners
General Contractors
Subcontractors

Q3 In the construction-related portion of your practice, what percentage (%) is devoted to the following types of construction?
Residential
Commercial
Industrial
Infrastructure (utilities, roads & bridges etc.)

Q4 In your experience, what percentage (%) of construction disputes are initiated by:
Project Owner
General Contractor
Subcontractor
Others (Please specify)

Q5 In your experience, what has been the actual amounts in controversy for construction disputes, by percentage (%)?
Less than $10,000
$10,000 - $100,000
$100,000 - $500,000
$500,000 - $1,000,000
$1,000,000 - $10,000,000
More than $10,000,000

Q6 In your experience, what percentage (%) of construction projects are governed by:
AIA contracts
ConsensusDOCS contracts
Other contract form (Please specify)
Custom

Q7 Which contracts do you/your clients use most frequently?
AIA contracts
ConsensusDOCS contracts
Other contract forms (Please specify) ____________________
Custom

Q8 In your experience, what are the five most common construction-related disputes?

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Disputed Issue</th>
<th>Is this associated with a particular contract type?</th>
<th>If yes, please specify</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Thank you for taking the time to fill out the survey. Your input is greatly appreciated.
REFERENCES


Assessment of Electrical Contractors’ Perception and Practices with Project Risk Management

Anthony J. Perrenoud, University of Oklahoma | perrenoud@ou.edu

ABSTRACT

Project Risk Management is a critical construction management skillset for identifying risks, assessing risks, strategizing, and executing risk mitigation plans. Proactive risk management has been found to reduce negative impacts to project objectives and increase customer satisfaction. To improve project risk management contractors have a method of measuring perceptions and practices of risk management, also known as risk maturity. Previous research has identified a model for measuring five major attributes of risk maturity they are (1) management’s perspective of risk management; (2) organizational risk culture; (3) risk identification; (4) risk analysis; and, (5) standardized risk management process. This study presents the risk maturity of seventy-one electrical contractors in the United States. The study finds that the contractors have high levels of trust within their companies and emphasis on managing project risks. However, the group is found to lack standard project risk management tools and communication methods. The study provides contractors a benchmark of the industry’s risk maturity and identifies opportunities in which project risk management can be improved in the industry.

Key Words: Project Risk Management, Risk Maturity

Anthony Perrenoud, Ph.D., CRIS is an Assistant Professor in the Haskell and Irene Lemon Construction Science Division at the University of Oklahoma. His research focuses on construction risk management, workforce development, leadership, and procurement practices.
INTRODUCTION

The complexity of construction projects is continuously increasing and requires improved management practices to deliver complex projects successfully. Risk management is a critical aspect of construction management. However, many contractors are unaware of the tools and practices available for managing project risk (Carter & Chinyio 2012). The term “risk management” is often ambiguous in the construction industry and often is considered to be the insurance and bonding aspects of construction. Risk management can focus on financial, strategic, hazard/safety or operational aspects (Rejda 2011). This paper focuses on operational risk management in the construction industry and refers to it as Project Risk Management (PRM).

Although PRM practices are as critical as estimating, scheduling, and cost controls practices, many companies lack consistent PRM practices and policies. Lack of awareness and lack of expertise is a common barrier found in research for improving contractor’s PRM capabilities (Carter & Chinyio 2012). Unlike other project management skills, PRM can be considered to be an intuitive skill that project managers inherit through experience. Similar to other project management skills, contractor’s perceptions and practices of PRM can be measured and is known as risk maturity. This paper presents an assessment of 71 electrical contractor’s risk maturity in the United States and identifies areas of opportunity for PRM improvement.

LITERATURE REVIEW

Project Risk Management

Due to the high exposure to risk in the construction industry, as well as the expressed impact of neglecting risks, Project Risk Management (PRM) has received much attention as an important component of successful project management (Dikmen et al. 2008; Hillson 1998; Perrenoud et al. 2015; Turner & Muller 2003; Wood & Ellis 2003). PRM has been found to reduce negative impacts to project objectives and increase customer satisfaction (Perrenoud et al. 2015). PRM has been found to reduce negative impacts to project objectives and increase customer satisfaction (Perrenoud et al. 2015). PRM practices to deliver complex projects successfully. Risk management is a critical aspect of construction management. However, many contractors are unaware of the tools and practices available for managing project risk (Carter & Chinyio 2012). The term “risk management” is often ambiguous in the construction industry and often is considered to be the insurance and bonding aspects of construction. Risk management can focus on financial, strategic, hazard/safety or operational aspects (Rejda 2011). This paper focuses on operational risk management in the construction industry and refers to it as Project Risk Management (PRM).

Risk identification is the process of determining and recording which risks may impact project objectives (PMI 2013). Organizations can adopt various tools and processes to their identification methods, such as checklists, brainstorming activities, diagramming techniques, retrospective analysis, risk breakdown structures, scenario analysis, SWOT analysis, interviews, and surveys (Edwards et al. 2009; Hillson 2003; Kasap & Kaymak 2007). Risk identification should be performed throughout the project but in particularly before the notice to proceed.

Risk Assessment

A risk assessment provides prioritization of the identified risks by the likelihood that a particular risk may occur and its impact to project objectives such as time and cost (Hillson 2003). Prioritization of risks will help allocate resources to provide risk mitigation solutions for the most critical risks. Estimating the likelihood of a risk’s occurrence should be done on a range such as: very low to very high chance of occurrence. Simultaneously, the impact of the risk should be estimated on a range such as a minor threat to the project to an extreme threat to the project (Hanna et al. 2013). Risks should be dismissed by project teams when the likelihood or impact is found to be not applicable. Various risk allocation tools are available within the industry to assist contractors with identifying the probability and impact of risks (Gibson et al. 2004; Hanna et al. 2013; Li et al. 2001).

Risk Response Plan

Once identified risks have been prioritized, project teams will be able to focus on critical risks strategically. A risk response plan will be created for the critical risks by developing a risk strategy and assigning individual action items. Complete transparency among team members with the response strategies will promote greater ownership of the risk solution and reduce upper management’s workload (Perrenoud et al. 2015). There are four basic options that teams have to respond to risks: eliminate the risk (avoidance); minimize the impact (mitigate); make it someone else’s problem (transfer); or do nothing and hope it doesn’t hurt too much (accept) (Kendrick, T 2015). The objective is to reduce the negative impact on the project’s objectives: cost, schedule, quality, satisfaction, etc. Risk management also incorporates taking positive risks to increase opportunities for success. Positive risk allocation methods often include exploiting, sharing, enhancing, and accepting. Akintoye & MacLeod (1997) found that contractors do not heavily favor a specific risk allocation method and they all treat risk differently. Determining the effective method for each risk is often at the discretion of the contractors. According to Zou et al. (2010), selecting and communicating the correct
allocation method for each identified risk is “second nature” to an organization with optimal capabilities.

Implementing and Improving PRM Practices

Structured processes have been developed to help implement PRM practices; organizations such as the Project Management Institute (PMI 2013) and The Institute of Risk Management (IRM 2016) provide PRM literature and training. A unified/generic risk management process based on the multiple standards and guidelines can be found in Hillson’s (2009) text. Although terminology differs between them, they tend to follow the same basic steps. The biggest obstacle to improving PRM in companies comes from a failure to manage the human aspect of the risk process (Hillson and Murray-Webster 2007). Employee perceptions related to PRM practices is often the biggest barrier to improving PRM practices. Models have been created to measure the implementation and perceptions of PRM within an organization, what is known as risk maturity.

Risk Maturity

Risk maturity has been defined as a company’s perception and practices of PRM (Perrenoud et al. 2017). Risk maturity reflects the sophistication of an organization’s understanding of its risk portfolio and how to manage those risks as well as the internal business continuity systems needed to cope with and recover from their eventuality (Zou et al. 2010). Hillson (1997) suggested that organizations wishing to implement a formal/structured approach to project risk management need to treat the implementation itself as a project, requiring clear objectives and success criteria, proper planning and resourcing, and active monitoring and control. Hillson (1997) recommended that organizations measure and benchmark their risk maturity using an accepted framework that provides an objective assessment of current maturity levels, assists in setting realistic targets for improvement and measures progress towards targeted improvements. In the absence of such a framework, Hillson drew from the already established Capability Maturity Model (CMM) (developed by the Software Engineering Institute at Carnegie-Mellon University) to create the Risk Maturity Model (RMM).

Risk Management Maturity Model (RM3)

Since the creation of the RMM, researchers have developed several maturity models for measuring organizations’ risk management capability. Zou et al. (2010) compared eight risk maturity models (see Table 1), and developed a risk maturity model specifically designed for construction organizations, called the Risk Management Maturity Model (RM3). The RM3 was tested and published in the American Society of Civil Engineering (ASCE) Journal of Construction Engineering and Management in 2010.

The RM3 consists of five attributes designed to test different aspects of an organization’s risk management capabilities (Zou et al. 2010). The five attributes of risk maturity are 1) management’s perspective of risk management; 2) organizational risk culture; 3) risk identification; 4) risk analysis; and, 5) standardized risk management process. Five questions were developed to assess each of the five attributes, for a total of twenty-five questions. The five questions for each attribute is presented in the “Findings” section below. For a full list of questions see Table 9. Respondents are provided a

<table>
<thead>
<tr>
<th>Year</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>Risk Maturity Model</td>
<td>Hillson, D.</td>
</tr>
<tr>
<td>2002</td>
<td>Risk Management Maturity Model</td>
<td>Risk Management Research and Development Program Collaboration</td>
</tr>
<tr>
<td>2003</td>
<td>Business Risk Management Maturity Model</td>
<td>International Association for Contract and Commercial Management</td>
</tr>
<tr>
<td>2004</td>
<td>Project Risk Maturity Model</td>
<td>Hopkinson, M. and Lovelock, G.</td>
</tr>
<tr>
<td>2004</td>
<td>Capability Maturity Model</td>
<td>Ren, Y. T. and Yeo K. T.</td>
</tr>
<tr>
<td>2006</td>
<td>RIMS Risk Maturity Model</td>
<td>Risk and Insurance Management, Inc.</td>
</tr>
<tr>
<td>2007</td>
<td>Information Risk Management Maturity Model</td>
<td>Lacey, D.</td>
</tr>
<tr>
<td>2007</td>
<td>Operational Risk Management Maturity Model</td>
<td>Fernando, A.</td>
</tr>
</tbody>
</table>
4-point Likert scale in which they select one of the four different levels of risk maturity for each question. The four levels of risk maturity reflect a 2002 publication of common risk maturity levels (RMDPC), see descriptions of each level in Table 2. Level 4 representing the highest possible risk maturity and Level 1 representing the lowest risk maturity.

The objective of this research was to utilize the RM3 and the four levels of risk maturity to benchmark the risk maturity of contractors to identify opportunities for PRM improvement. The findings from the research provide contractors direction for improving internal perceptions and practices with PRM.

**METHODOLOGY**

ELECTRI International is a research foundation for electrical construction affiliated with the
National Electrical Contractors Association (NECA). In
2015, ELECTRI International initiated a project to measure the risk maturity of NECA contractors. The twenty-five questions from the RM3 (see Table 9) were used by the author to develop an online survey tool with Qualtrics®, an online survey software that collects data for research. The survey also included demographic questions to compare different characteristics of companies. The survey provided four possible responses based on a 4-point Likert scale (with 4 representing the highest risk maturity and 1 being the lowest risk maturity). The breakdown of scores identifying the levels of risk maturity was:

- Level 1 = 1.0-1.99
- Level 2 = 2.0-2.99
- Level 3 = 3.0-3.99
- Level 4 = 4.0

An invitation to participate in the research was sent to NECA contractors by ELECTRI International with a link to the online survey tool. To provide an incentive for survey participation, respondents had the option to receive an individual risk maturity report that would compare their companies risk maturity to other NECA contractors. Complete confidentiality was ensured to protect the company’s information. Upon completion of data collection, the researcher provided individual contractors a risk maturity report that identified PRM strengths and weaknesses within their companies. The researcher performed Pearson Correlation tests for identifying correlations between demographics of the companies and the overall risk maturity. The Pearson correlation coefficient ($r$) determines the strength of the correlation: a strong correlation is represented by an $r$-value greater than .5; a medium correlation is represented by an $r$-value between 0.3 and 0.5 (Cohen 1988).

**FINDINGS**

During the scheduled data collection period, seventy-one contractors provided valid survey responses. Figures 1 thru 4 present the demographics of the construction firms that responded. All respondents were located in the United States. The majority of the companies were focused on commercial construction, established before 1954, employed more than 100 workers, and a near-majority had annual revenue of more than fifty million USD.
Risk Maturity Level

The 71 survey responses provided the data to benchmark the contractor’s risk maturity levels. Table 3 presents the percentage of contractors that were identified for each of the four levels of risk maturity. The majority (51%) of the contractors were identified as Level 2 – Repeatable contractors. None of the contractors were identified as a Level 4 – Optimized contractor.

Additionally, Table 3 presents the average risk maturity score of 2.51, which signifies that the average electrical contractor was measured at a Level 2 – Repeatable maturity level (RMDPC).

Table 3. Risk Maturity Level

<table>
<thead>
<tr>
<th>Risk Maturity Level</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>21%</td>
<td>51%</td>
<td>28%</td>
<td>0%</td>
<td></td>
<td>2.51</td>
</tr>
</tbody>
</table>

The average risk maturity score demonstrates that there are both strengths and weaknesses of the industry’s current PRM processes. Figure 6 presents a spider chart of the average scores with each of the five risk maturity attributes. Organizational risk culture was found to be the highest ranked at 2.88, followed by management’s perspective of risk management (2.64); risk identification (2.46); standardized risk management process (2.29); and finally risk analysis (2.27). The following discussion breaks down the findings from the five attributes.

Management Perspective of Risk Management

Table 4 presents the scores from the five questions related to management’s perspective of risk management. The second highest rated question overall (3.21) was from question #1 which provides support that PRM is very important to upper management within the group.

Table 4. Management Perspective of Risk Management Attribute

<table>
<thead>
<tr>
<th>#</th>
<th>Question</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Upper managements support and encouragement with risk management.</td>
<td>0%</td>
<td>8%</td>
<td>62%</td>
<td>30%</td>
<td>3.21</td>
</tr>
<tr>
<td>2</td>
<td>Assessment of risk management capabilities within company.</td>
<td>25%</td>
<td>35%</td>
<td>27%</td>
<td>13%</td>
<td>2.27</td>
</tr>
<tr>
<td>3</td>
<td>Communication of risk management information to all project participants.</td>
<td>11%</td>
<td>31%</td>
<td>38%</td>
<td>20%</td>
<td>2.66</td>
</tr>
<tr>
<td>4</td>
<td>Integration of risk management tools and techniques used on projects.</td>
<td>27%</td>
<td>25%</td>
<td>32%</td>
<td>15%</td>
<td>2.37</td>
</tr>
<tr>
<td>5</td>
<td>Proper allocation of resources to project risk.</td>
<td>17%</td>
<td>4%</td>
<td>70%</td>
<td>8%</td>
<td>2.70</td>
</tr>
</tbody>
</table>

Management Attribute Average Score

<table>
<thead>
<tr>
<th></th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management Attribute</td>
<td>13%</td>
<td>48%</td>
<td>38%</td>
<td>1%</td>
<td>2.64</td>
</tr>
</tbody>
</table>
Organization Risk Culture

Table 5 presents the scores from the five questions related to the risk culture within the group. This attribute was the highest rated (2.88) and shows positive signs that a working culture exists within the individual organizations. The highest rated question (#6) provided clear evidence that a high level of trust exists within these companies (3.35). This culture of trust increases communication of issues and allow for more transparency with risk mitigation. When trust is present employees are encouraged to communicate project risk to their companies and leadership commends them when they do, rarely will employees hide issues out of fear of consequences. Workers among the contractors have high levels of risk ownership (3.04) which suggests they often understood their responsibilities within the PRM process (question # 7). Question # 8 indicates that risk responsibilities are assigned to team members (2.82). Question #9 (2.69) provides the research’s first insight that risk communication is frequent. However, 38 percent of contractors do not use a standard communication tool or method for risks to be communicated by project members. Previous research has identified that formal risk communication tools provide greater transparency and measurements with PRM (Perrenoud et al., 2013). The final question, #10, (2.52) shows that many companies have accepted PRM practices within their company’s Standard Operating Procedures (SOP) and some offer training. Overall the culture within the group is very positive when it comes to the perceptions and practices of risk management; this provides optimistic signs that the contractors desire to have successful risk management practices within their teams.

Risk Identification

Deficiencies in risk management were identified in the following three attributes, beginning with the attribute of identifying risk on projects. Table 6 presents the scores from the five questions related to identifying risk. Identifying risks during the planning stages of the project was found to be done on most projects (question #11 2.68). Question # 12 (2.30) 46 percent of the companies allowed the project team members to select the risk identification process, compared to 54 percent of the companies that require a risk identification process. Communication with project risks to the entire project team was done informally, i.e., word of mouth, individual email, etc. with 40 percent of the contractors (question # 13, 2.63). Often only the risks that the teams are concerned with getting reported, leaving potential risks uncommunicated and/or unanalyzed. Question #14 (2.30) identified that the majority (67%) of the contractors leave it to the discretion of the project teams whether to perform a risk identification process consistently through the project lifecycle. Finally, the research identified that 55 percent of the contractors rarely compare actual project impacts to the risks identified during the project (question # 15). The central insight that is identified is that most contractors identify project risks in the planning stages of construction. However, nearly half (46%) of the contractors allow the project team members to decide how they will identify risk. With PRM being a critical project management skill a large number of contractors should be concerned with developing risk identification tools and processes.

Risk Analysis

The lowest scoring attribute was found to be risk analysis (2.27), Table 7 presents the scores from the five questions related to this attribute. The lower score is not surprising to the researcher as this area of risk management often lacks definition within construction companies. Positive findings from the research show that the contractors usually do try to prioritize risks (question #17) to allocate

Table 5. Organizations Risk Culture Attribute

<table>
<thead>
<tr>
<th>#</th>
<th>Question</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Level of trust within organizations in relation to risk management.</td>
<td>0%</td>
<td>8%</td>
<td>48%</td>
<td>44%</td>
<td>3.35</td>
</tr>
<tr>
<td>7</td>
<td>Ownership of risks assigned to individual team members.</td>
<td>1%</td>
<td>11%</td>
<td>69%</td>
<td>18%</td>
<td>3.04</td>
</tr>
<tr>
<td>8</td>
<td>Proper delegation of risk ownership and management.</td>
<td>13%</td>
<td>17%</td>
<td>46%</td>
<td>24%</td>
<td>2.82</td>
</tr>
<tr>
<td>9</td>
<td>Open communication within the company when a risk occurs on a project.</td>
<td>3%</td>
<td>35%</td>
<td>52%</td>
<td>10%</td>
<td>2.69</td>
</tr>
<tr>
<td>10</td>
<td>Acceptance of risk management within the organization.</td>
<td>24%</td>
<td>21%</td>
<td>34%</td>
<td>21%</td>
<td>2.52</td>
</tr>
</tbody>
</table>

Culture Attribute Average Score

<table>
<thead>
<tr>
<th></th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7%</td>
<td>44%</td>
<td>44%</td>
<td>6%</td>
<td>2.88</td>
<td></td>
</tr>
</tbody>
</table>
Assessment of Electrical Contractors’ Perception and Practices with Project Risk Management

Table 6. Risk Identification Attribute

<table>
<thead>
<tr>
<th>#</th>
<th>Question</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Identification of risks on new projects.</td>
<td>7%</td>
<td>31%</td>
<td>49%</td>
<td>13%</td>
<td>2.68</td>
</tr>
<tr>
<td>12</td>
<td>Systematic method to identify risks.</td>
<td>35%</td>
<td>11%</td>
<td>42%</td>
<td>11%</td>
<td>2.30</td>
</tr>
<tr>
<td>13</td>
<td>Method for collecting and communicating project risks to project team.</td>
<td>7%</td>
<td>37%</td>
<td>42%</td>
<td>14%</td>
<td>2.63</td>
</tr>
<tr>
<td>14</td>
<td>Identified risks are revised and reevaluated throughout the project process.</td>
<td>11%</td>
<td>56%</td>
<td>24%</td>
<td>8%</td>
<td>2.30</td>
</tr>
<tr>
<td>15</td>
<td>Post project evaluation of the risk identification process.</td>
<td>13%</td>
<td>41%</td>
<td>38%</td>
<td>8%</td>
<td>2.42</td>
</tr>
</tbody>
</table>

Identification Attribute Average Score

<table>
<thead>
<tr>
<th>#</th>
<th>Question</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>Capability of the project team to analyze project risk.</td>
<td>24%</td>
<td>38%</td>
<td>32%</td>
<td>6%</td>
<td>2.20</td>
</tr>
<tr>
<td>18</td>
<td>Capability to identify the likelihood and impact of risk.</td>
<td>18%</td>
<td>37%</td>
<td>32%</td>
<td>13%</td>
<td>2.39</td>
</tr>
<tr>
<td>19</td>
<td>Utilization of risk analysis tools.</td>
<td>48%</td>
<td>15%</td>
<td>25%</td>
<td>11%</td>
<td>2.00</td>
</tr>
<tr>
<td>20</td>
<td>Risk assessment drives decision making.</td>
<td>39%</td>
<td>14%</td>
<td>34%</td>
<td>13%</td>
<td>2.20</td>
</tr>
<tr>
<td></td>
<td>Prioritization of risks occurs to focus on major risks.</td>
<td>21%</td>
<td>21%</td>
<td>39%</td>
<td>18%</td>
<td>2.55</td>
</tr>
</tbody>
</table>

Analysis Attribute Average Score

Table 7. Risk Analysis Attribute

<table>
<thead>
<tr>
<th>#</th>
<th>Question</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Identification of risks on new projects.</td>
<td>7%</td>
<td>31%</td>
<td>49%</td>
<td>13%</td>
<td>2.68</td>
</tr>
<tr>
<td>17</td>
<td>Systematic method to identify risks.</td>
<td>35%</td>
<td>11%</td>
<td>42%</td>
<td>11%</td>
<td>2.30</td>
</tr>
<tr>
<td>18</td>
<td>Method for collecting and communicating project risks to project team.</td>
<td>7%</td>
<td>37%</td>
<td>42%</td>
<td>14%</td>
<td>2.63</td>
</tr>
<tr>
<td>19</td>
<td>Identified risks are revised and reevaluated throughout the project process.</td>
<td>11%</td>
<td>56%</td>
<td>24%</td>
<td>8%</td>
<td>2.30</td>
</tr>
<tr>
<td>20</td>
<td>Post project evaluation of the risk identification process.</td>
<td>13%</td>
<td>41%</td>
<td>38%</td>
<td>8%</td>
<td>2.42</td>
</tr>
</tbody>
</table>

Identification Attribute Average Score

<table>
<thead>
<tr>
<th>#</th>
<th>Question</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Capability of the project team to analyze project risk.</td>
<td>24%</td>
<td>38%</td>
<td>32%</td>
<td>6%</td>
<td>2.20</td>
</tr>
<tr>
<td>17</td>
<td>Capability to identify the likelihood and impact of risk.</td>
<td>18%</td>
<td>37%</td>
<td>32%</td>
<td>13%</td>
<td>2.39</td>
</tr>
<tr>
<td>18</td>
<td>Utilization of risk analysis tools.</td>
<td>48%</td>
<td>15%</td>
<td>25%</td>
<td>11%</td>
<td>2.00</td>
</tr>
<tr>
<td>19</td>
<td>Risk assessment drives decision making.</td>
<td>39%</td>
<td>14%</td>
<td>34%</td>
<td>13%</td>
<td>2.20</td>
</tr>
<tr>
<td>20</td>
<td>Prioritization of risks occurs to focus on major risks.</td>
<td>21%</td>
<td>21%</td>
<td>39%</td>
<td>18%</td>
<td>2.55</td>
</tr>
</tbody>
</table>

Analysis Attribute Average Score

resources appropriately to the most critical risks (question #20). Question #16 (2.20) finds that only 40% of project team members can analyze risk, typically those that have many years of experience. A big part of the problem may be that contractors are not familiar with risk analysis tools. Question #18 (2.00) identified that 63 percent of teams don’t have tools to analyze risk or the tools for analyzing risk have significant deficiencies. Finally, any risk analysis that was performed had little to no impact on the decision making process with 54 percent of the contractors when it came to planning risk responses (question # 19, 2.20). The low level of maturity found with risk analysis creates concerns that many project teams are not allocating appropriate levels of resources to mitigate the most critical risks. The author recommends that construction companies provide additional training and tools to employees for analyzing risk.

Standardized Risk Management

Table 8 presents the scores from the five questions related to standardizing PRM practices internally. This final attribute identified a weakness that contractors do not consistently manage risks across projects. It was found that 70 percent of project teams were inconsistent with PRM from project to project (question # 21). Responses to both questions #24 (2.18) and #25 (2.11) supported that contractors don’t have a standard method for managing project risk. This supports the previous findings from question #12 that risk management is left to the project managers on how risk will be identified, analyzed, and communicated. Question #23 provides evidence that risk management is often considered an important aspect of managing with 60% of contractors agreeing that PRM is a standard business practice. Additionally, 69 percent of respondents make at least some effort to communicate risk throughout the project life-cycle (question # 22).

Risk Maturity Testing

Table 9 presents the questions in ranked order of overall risk maturity average score. This table presents the questions that scored the highest on the top and the lowest on the bottom. Contractors can view the lowest ranked item as possible opportunities to improve PRM practices and perceptions that are readily achievable. Upon testing correlations between the risk maturity attribute scores and the demographics of the contractors, no initial correlations were identified. These findings indicate that location, size, type, and annual
Table 8. Standardized Risk Management Attribute

<table>
<thead>
<tr>
<th>#</th>
<th>Question</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Consistent risk management process.</td>
<td>15%</td>
<td>55%</td>
<td>18%</td>
<td>11%</td>
<td>2.25</td>
</tr>
<tr>
<td>22</td>
<td>Communication of risk management throughout the project life cycle.</td>
<td>14%</td>
<td>17%</td>
<td>55%</td>
<td>14%</td>
<td>2.69</td>
</tr>
<tr>
<td>23</td>
<td>Risk management is a standard business practice.</td>
<td>31%</td>
<td>30%</td>
<td>28%</td>
<td>11%</td>
<td>2.20</td>
</tr>
<tr>
<td>24</td>
<td>Standard risk management process across all projects.</td>
<td>45%</td>
<td>8%</td>
<td>30%</td>
<td>17%</td>
<td>2.18</td>
</tr>
<tr>
<td>25</td>
<td>Review of standard risk management process.</td>
<td>49%</td>
<td>7%</td>
<td>27%</td>
<td>17%</td>
<td>2.11</td>
</tr>
</tbody>
</table>

|                      | Process Attribute Average Score | 44%     | 25%     | 27%     | 4%      | 2.29 |

Table 9. Ranked Order of Questions by Risk Maturity Score

<table>
<thead>
<tr>
<th>#</th>
<th>Question</th>
<th>Rank</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Level of trust within organizations in relation to risk management.</td>
<td>1</td>
<td>3.35</td>
</tr>
<tr>
<td>1</td>
<td>Upper management support and encouragement with risk management.</td>
<td>2</td>
<td>3.21</td>
</tr>
<tr>
<td>7</td>
<td>Ownership of risks assigned to individual team members.</td>
<td>3</td>
<td>3.04</td>
</tr>
<tr>
<td>8</td>
<td>Proper delegation of risk ownership and management.</td>
<td>4</td>
<td>2.82</td>
</tr>
<tr>
<td>5</td>
<td>Proper allocation of resources to project risk.</td>
<td>5</td>
<td>2.70</td>
</tr>
<tr>
<td>9</td>
<td>Open communication within the company when a risk occurs on a project.</td>
<td>6</td>
<td>2.69</td>
</tr>
<tr>
<td>22</td>
<td>Communication of risk management throughout the project lifecycle.</td>
<td>7</td>
<td>2.69</td>
</tr>
<tr>
<td>11</td>
<td>Identification of risks on new projects.</td>
<td>8</td>
<td>2.68</td>
</tr>
<tr>
<td>3</td>
<td>Communication of risk management information to all project participants.</td>
<td>9</td>
<td>2.66</td>
</tr>
<tr>
<td>13</td>
<td>Method for collecting and communicating project risks to project team.</td>
<td>10</td>
<td>2.63</td>
</tr>
<tr>
<td>20</td>
<td>Prioritization of risks occurs to focus on major risks.</td>
<td>11</td>
<td>2.55</td>
</tr>
<tr>
<td>10</td>
<td>Acceptance of risk management within the organization.</td>
<td>12</td>
<td>2.52</td>
</tr>
<tr>
<td>15</td>
<td>Post project evaluation of the risk identification process.</td>
<td>13</td>
<td>2.42</td>
</tr>
<tr>
<td>17</td>
<td>Capability to identify the likelihood and impact of risk.</td>
<td>14</td>
<td>2.39</td>
</tr>
<tr>
<td>4</td>
<td>Integration of risk management tools and techniques used on projects.</td>
<td>15</td>
<td>2.37</td>
</tr>
<tr>
<td>12</td>
<td>A systematic method to identify risks.</td>
<td>16</td>
<td>2.30</td>
</tr>
<tr>
<td>14</td>
<td>Identified risks are revised and reevaluated throughout the project process.</td>
<td>17</td>
<td>2.30</td>
</tr>
<tr>
<td>2</td>
<td>Assessment of risk management capabilities within the company.</td>
<td>18</td>
<td>2.27</td>
</tr>
<tr>
<td>21</td>
<td>Consistent risk management process.</td>
<td>19</td>
<td>2.25</td>
</tr>
<tr>
<td>16</td>
<td>The capability of the project team to analyze project risk.</td>
<td>20</td>
<td>2.20</td>
</tr>
<tr>
<td>19</td>
<td>Risk assessment drives decision making.</td>
<td>21</td>
<td>2.20</td>
</tr>
<tr>
<td>23</td>
<td>Risk management is a standard business practice.</td>
<td>22</td>
<td>2.20</td>
</tr>
<tr>
<td>24</td>
<td>Standard risk management process across all projects.</td>
<td>23</td>
<td>2.18</td>
</tr>
<tr>
<td>25</td>
<td>Review of the standardized risk management process.</td>
<td>24</td>
<td>2.11</td>
</tr>
<tr>
<td>18</td>
<td>Utilization of risk analysis tools.</td>
<td>25</td>
<td>2.00</td>
</tr>
</tbody>
</table>
revenue have no impact on the attribute scores. Future research could examine if there are correlations between risk maturity scores and PRM training, adoption of PRM tools, and PRM performance metrics. Future research could also study the correlation between the amount of resources contractors devote to PRM compared to other critical project management tasks such as cost management, schedule management, quality management, human resources, etc.

Finally, correlations between the demographics and the risk maturity scores were tested. Pearson correlation testing found positive correlations between the size of the companies and their risk maturity scores. Table 10 presents the scores of the five attributes and the overall risk maturity by the number of employees within the company. Table 11 presents the scores by the size of annual billings.

The results of the Pearson’s correlation indicated a strong positive correlation ($r = .431$) between overall risk maturity and the number of employees. Additionally, testing found a strong positive correlation ($r = .489$) between overall risk maturity and the annual revenues. Both correlations infer that as companies grow in size and work, risk maturity increases. With the growth of the company and projects, complexity increases and requires improved PRM practices and perceptions. Testing was unable to identify any additional correlations between the demographics of the companies and their risk maturity scores.

### Conclusions and Recommendations

Project Risk Management (PRM) is a critical construction management skillset. Proactive risk management has been found to reduce negative project impacts and increase customer satisfaction. To improve PRM contractors must have a method of measuring perceptions and practices of risk

<table>
<thead>
<tr>
<th>Table 10. Risk Maturity Scores, Number of Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>N(71)</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>1 to 4</td>
</tr>
<tr>
<td>5 to 9</td>
</tr>
<tr>
<td>25 to 49</td>
</tr>
<tr>
<td>25 to 49</td>
</tr>
<tr>
<td>50 to 99</td>
</tr>
<tr>
<td>100 or more</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 11. Risk Maturity Scores, Annual Revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td>N(71)</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Less than $250,000</td>
</tr>
<tr>
<td>$250,000 to $999,999</td>
</tr>
<tr>
<td>$1,000,000 to $4,999,999</td>
</tr>
<tr>
<td>$5,000,000 to $19,999,999</td>
</tr>
<tr>
<td>$20,000,000 to $49,999,999</td>
</tr>
<tr>
<td>$50 Million or more</td>
</tr>
</tbody>
</table>
management, also known as risk maturity. Previous research has identified a model for measuring five major attributes of risk maturity they are (1) management’s perspective of risk management; (2) organizational risk culture; (3) risk identification; (4) risk analysis; and, (5) standardized risk management process. An online survey was utilized to collect data and to categorize contractor risk maturity in four different risk maturity levels, with Level 4 representing the highest risk maturity and Level 1 representing the lowest.

The objective of this study was to measure the risk maturity of electrical contractors and to provide a benchmark for the industry.

Seventy-one electrical contractors participated in the study. The group was found to have an overall Level 2 (2.51) risk maturity on average. A Level 2 contractor demonstrates necessary PRM capabilities on a project to project basis, but not consistently. One in five (21%) of the electrical contractors were found to be at a Level 1, which indicates that these contractors lack basic PRM knowledge and expertise. Collectively the group was found to have several healthy aspects of risk maturity, such as high levels of support from upper management; high levels of risk allocation and risk ownership on projects; and high levels of trust and communication within the organizations. However, the group also had opportunities for improvement with risk maturity attributes, such as promoting consistent risk identification methods throughout the project life-cycle; introducing risk assessment tools to help prioritization and decision making; and standardizing risk management methods and communication across project portfolios.

Contractors that are looking to improve or implement PRM practices must consider it similar to a construction project that requires precise objectives, success criteria, and performance measurement. The attributes and questions presented in this paper present a tool that can be utilized to improve PRM. This study provides an advance to the body of knowledge by presenting, (1) a benchmark for electrical contractors to evaluate their PRM practices and perceptions, (2) areas of strengths and weaknesses with risk maturity, and (3) a strong positive correlation between larger contractors and higher risk maturity scores. Contractors are highly recommended to review and improve capabilities consistently using the questions provided in the risk maturity survey.

References


Collaborative Risk Mitigation Through Construction Planning and Scheduling

Risk Doesn’t have to be a Four Letter Word

Dr Lana Kay Coble, CPC

"Lana Coble is one of those rare technical talents that can explain those concepts but also specifically mentor folks in how to pull them off successfully...and in Lana's case, in an emotionally intelligent manner. Read this book several times. It's like a good novel, you will learn something new each time."
Wayne O'Neill, CEO RESET

"Lana's depth of experience makes her extremely qualified to walk the reader through the challenges of large capital projects. She brings case-study experience to illuminate her concepts and assist the reader to better comprehend the ideas she wishes to share."
Sidney J Sanders, Senior Vice President, Construction, Facilities Design and Real Estate, Houston Methodist

In the complex, cash-strapped, high risk world of modern construction, what do you do when something goes wrong? This new book by Dr Lana Coble looks beyond the best-case scenario to give project managers, contractors, architects, engineers and subcontractors the tools to prepare effectively for the unexpected.

Based on the author’s more than thirty-eight years of construction management experience, the book shows how to proactively mitigate a schedule. It opens with case studies of real life construction mitigation, and goes on to examine the conceptual aspects of anticipating risks and preparing contingency plans, technical aspects of scheduling, and essential role of communication in change management.

Methods are provided which facilitate inclusion of the highest risk activities into the project schedule. Additional tools are included which communicate schedule change-management and building activation.

Working on the principle that no major project can ever quite go to plan and that “it's not how you start, it's how you finish,” this is the ideal complement to traditional scheduling textbooks.