**Journal of Construction Engineering and Management**

Exposing Uncertainty in Bid Preparation of Steel Construction Cost Estimating: II. Comparative Analysis and Quantitative C-I-V-I-L Classification  
--Manuscript Draft--

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<td><strong>Contributions to the Body of Knowledge</strong></td>
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Each paper published in the JCEM must contribute to the field of Construction Engineering and Management. Authors must consider how their new knowledge and/or innovations add value to the industry. Please outline the specific contributions of this research in this Box. These points are best conveyed in a list or outline format and must demonstrate how this work is unique and expands the Point of Departure.

To read more about how the JCEM considers each paper’s contributions please see the following Editor's Note.
Gunnar Lucko, Ph.D.
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Catholic University of America
Pangborn Hall Room G-17
620 Michigan Avenue NE
Washington, DC 20064

Dear Editor,

please find attached the electronic files by Abdulhamit Kayihan Duzkale and Gunnar Lucko for:

- “Exposing Uncertainty in Bid Preparation of Steel Construction Cost Estimating: I. Conceptual Framework and Qualitative C-I-V-I-L Classification” (COENG-4355, Decline with Recommendation to Resubmit) with supplemental data that contains a list of all detailed minor uncertainty types that are aggregated into major types, and its companion paper:


We respectfully ask that both manuscripts be jointly reviewed by Journal of Construction Engineering and Management as one technical paper and one case study, respectively.

We would like to apologize to the reviewers for the fact that – unexpected and unknown to us – the editor’s kind encouragement of the editor to submit our substantial material in format of one technical paper plus one case study caused these two companion papers to be split among two different groups of anonymous reviewers, who noted regretfully the lacking of the other paper.

In this resubmittal / re-review, we have reworked / revised both manuscripts according to the helpful feedback from these reviewers. Additionally, we provide the respective other paper as an attachment in the PDF submittal file itself for the convenience of the reviewers. Both papers are written to stand on their individual merit, but are intended as complementary companion papers.

Companies gave permission to use their data under confidentiality agreements (enclosed). You can contact us at lucko@cua.edu if needed. Thank you very much for your kind consideration.

Sincerely,

Gunnar Lucko
Associate Professor and Director, Construction Engineering and Management Program
Exposing Uncertainty in Bid Preparation of Steel Construction Cost Estimating:

II. Comparative Analysis and Quantitative C-I-V-I-L Classification

By Abdulhamit Kayihan Duzkale 1, Ph.D., A.M.ASCE, and Gunnar Lucko 2, Ph.D., A.M.ASCE

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Abstract

Bid prices vary greatly depending on assumptions for uncertain conditions. In steel construction bidding, contingency amount is typically used as a bid line item to factor in the unexpected – including impact of uncertainty – to the lump sum bid price. Therefore the goal of this research is to explore impacts of uncertainties that contribute to contingency amount. The costs of uncertainties in bid documents of the real-world school projects have been calculated. Contributions to the body of knowledge are (1) providing illustrative examples of real-world uncertainties from the data set; (2) statistically analyzing the relative occurrence and cost significance to increase estimators’ awareness when they evaluate uncertainties; and (3) comparing the cost significance from the data with officially recommended contingency percentages. This research enables that steel estimators can make quantitative-based decisions on
contingency in their estimates should various major types of uncertainties still be encountered
without any opportunity to resolve them.

**Keywords:** Construction estimating; bid uncertainty; bid document; bid accuracy; quantity
takeoff; structural steel.

**Introduction**

Different types of uncertainties can result in significant overestimation or underestimation in
cost elements. Overestimating any cost element within a project can cause a bidder to lose the
bid and can create excessive cost for the owner if all bidders make conservative assumptions for
an uncertain item. Underestimating can lose reputation and money if a bidder withdraws after the
bid opening and loses their investment in a bid bond. It can also cause problems for the owner if
the low bidder is awarded the contract, but then fails to complete the construction project due to
financial problems. Bid prices vary greatly depending on assumptions for uncertain conditions.
Contractors therefore attempt to protect themselves from the cost of uncertainties by adding a
line item called contingency to the budget (Mak and Picken 2000; DOE 1997). However, current
practice still bases this amount on experience of individual project managers (Günhan and Arditi
2007), and fails to address the root cause for such need to include contingency – the existence of
uncertainty in bid documents themselves. In the companion paper, Duzkale and Lucko (2015)
explored, detected, and identified the uncertainties in bid documents to increase the awareness of
steel estimators. These uncertainties have been categorized in a taxonomy based on a framework
of information flow as it is observed from the data between bid participants. The resolution
approaches for current practice have been made in a theoretical context. This paper statistically analyzes said uncertainty in form of its new categories in terms of their quantities and costs.

Significance of Uncertainty Impact Analysis of Bid Documents

Ho and Liu (2004, p. 103) stated that “inevitable ambiguities or deficiencies exist in contract documents and the builder should be well prepared for the need to recover the damage.” Carr (1989, p. 550) emphasized that “worst of it… is not to know when one does not know, not to know when to expect error, and not to provide for the occurrence of expected. An estimator is strongly interested in accuracy, which demands knowledge of what will occur.” To address these challenges, this research equips steel estimators with knowledge on types of uncertainties, their occurrences, and magnitudes, here exemplarily for school projects. Types of uncertainties have been studied in the companion paper (Duzkale and Lucko 2015), and their occurrences and magnitudes will be analyzed in this paper. The approach provided herein can eventually yield several potential improvements in practice, which are presented here in chronological order:

- Knowing the impact of an uncertainty that can be encountered during the initial bid document review requires experience. An estimator equipped with such knowledge can prioritize and react to heal or alleviate the consequences to be dealt with by all participants of the project.
- The cost of uncertainties that are not resolved during bid preparation can become a growing burden for the project owner. Change order pricing of construction components is often higher than bid pricing due to the absence of competition once the project has been awarded. In other words, it is both the bidders’ and owners’ best interest to capture uncertainties as early as it is possible. As Safin et al. (2008, p. 1060) explained, the “[I]ater the error is detected, [the] greater
are the consequences and the difficulty to recover [from] the error.” With reduced uncertainties in the bid documents, the owner budgets would be more aligned with their financed funds;

- A reduced number of lawsuits and lien filings can result, because fewer contractor-owner conflicts may arise from uncertainties in bid documents that were unresolved until it was too late.

### Previous Work

The companion paper (Duzkale and Lucko 2015) has created a taxonomy that condensed minor types into 5 major uncertainty types and captured them in a mnemonic (C-I-V-I-L). It then has created a framework that has represented information flow between project participants as equalities or inequalities to understand possible causes of uncertainties. Minor types that have been identified in the data from nine public school projects across the Washington metropolitan area have been categorized into five major types as shown in bold italics in Appendices A1-A5 of the companion paper. Instead of repeating the entire aforesaid framework, Figure 1 is an alternative representation that uses set theory, which is provided to summarize the major types that the companion paper has established. In Figure 1a, Conflicting pieces of information – shown with different shapes – are provided by architect, structural engineer, and code. Shaded areas represent the ‘uncertainty locale’ from where the estimating assumptions can be drawn. Partially shaded shapes in Figure 1b show Incomplete information, where the missing portion – part of the construction domain – is not provided in the documents. Figure 1c represents an uncertainty of the Vague type, where the shaded area shows that any assumption may be possible. An uncertainty of the Incorrect type is denoted with the empty set in Figure 1d. Note that the final type discussed in the companion paper, Lack of Work Assignment, is not shown, because it has been found that its output – but not input – resembles that of the Conflicting type.
Research Questions and Hypothesis

This study seeks to address the following research question as detailed in a list of subquestions:

“How uncertainty categories compare in terms of their impact on cost?”

More specifically, the subquestions are (1) what is the significance in terms of the absolute and relative cost impact of each major type of uncertainty; and (2) are empirical contingencies that are often suggested and used of an order of magnitude and range of values that cover the actual bid document uncertainties and other risks? The hypothesis established for this is:

“H1: Significant quantity and cost differences exist between major types of uncertainties.”

To test this hypothesis, bid documents of the school projects in Washington metropolitan area with structural steel framing will be investigated and a detailed line-item quantity takeoff will be performed under the most stringent assumptions for each uncertainty data point, i.e. using the worst-case scenario of the cost of missing information or the most costly alternative if conflicting information occurs, to establish a consistent upper bound for the anticipated impact. Material cost and equipment rental rate data will be collected from regional suppliers, labor rates will employ the U.S. Department of Labor salary survey, and overhead cost will be gathered from actual cost of a steel company in the same region where data are collected.

Uncertainty cost to total cost ratios will be calculated for each type uncertainty. A statistical analysis of the quantity takeoff data and major uncertainty types will be conducted to measure the cost impact difference between the uncertainty types. Non-parametric bootstrapping method will be used to address the limitation in the number of data points due to the substantial effort in
deriving each data point. The broader term ‘uncertainty’ is chosen over ‘error’ to indicate that it arises as a matter of interpretation.

Research Goal and Objectives

The goal of this research is to investigate the impact of uncertainties that occur in bid documents. This goal will be achieved by processing data from actual bid documents and quantifying their impacts on cost statistically. Research objectives are formulated as follows:

- **Research Objective 1 (Demonstration):** In the context of a case study, define and illustrate the major uncertainty types that have been defined based on the taxonomy and explained with the taxonomy of the companion paper with representative samples from the data set. This will aid in a rapid dissemination by enabling practitioners to unambiguously understand these types and implement the key results of this research in preparing their steel estimates;

- **Research Objective 2 (Quantification):** Rank the major uncertainty types in the taxonomy that have been gained from the companion paper based on statistical analysis of actual data of structural steel plan documents, and assess their relative occurrence and cost significance;

- **Research Objective 3 (Evaluation):** Compare in the order or magnitude and value of suggested contingency percentages from current practice with the results from this research.

Research Scope, Assumptions, and Limitations

The scope of this research specifically includes cost and impact of the design uncertainties within the bid documents for structural steel framing. The exemplary data that are selected for this research are public school projects from the Washington metropolitan area (consisting of Washington, DC, Northern Virginia, and Maryland), which contain substantial amounts of
structural steel. Besides, they feature a uniform design and their data are readily accessible from the public owners of the respective school systems. Three of the nine school projects in the data were located in each state for an even coverage. The substantial amounts of plan drawing and specification pages that have been analyzed per project are listed in Table 2 of the companion paper (Duzkale and Lucko 2015). These school projects have similar structural design characteristics. Each project design had structural steel framing that consisted of steel beams and columns plus steel joists on load-bearing masonry walls. The design loads and the overall geometry of the structures were similar due to close geographical proximity of the projects and typical functional requirements for the intended users. The word ‘plan’ in this research study will mean all of the design drawings, which can be elevations and sectional, detail, and top views.

This research employs several assumptions to enable performing detailed quantity takeoffs, which are consistent across all data points and align with accepted estimating practice. Structural steel prices are collected from three regional suppliers, i.e. warehouse pricing is included in the dataset instead of steel mill pricing for three reasons. Mills may have several months of lead time due to their rolling schedules, whereas material is usually immediately available if procured locally. Moreover, shapes and sizes of the structural steel in school projects vary greatly due to variation in design intent and functions of spaces, which cannot be easily accommodated by mills. Furthermore, mills require minimum order quantities that are infeasible for single projects.

Equipment rental prices from three regional companies are used. Types of rental equipment assumed in pricing the steel installation are duct lifts, scissor lifts, boom manlifts, and boom forklifts. Three different crane rental companies provide price quotations for truck cranes. The Bureau of Labor Statistics ((BLS 2010b) compensation survey for the National Capital Region (Washington, District of Columbia, parts of Maryland, and Northern Virginia) provides costs for
each labor classification that is involved in office and fabrication activities. For any field labor, the Davis-Bacon Wage Determination Act’s (DOL 2014) labor rates are used. Fabrication and erection of structural steel are assumed to be performed in accordance with current American Institute of Steel Construction (AISC) Code of Standard Practice (2005) guidelines. The designer’s (i.e. architect and/or engineer) knowledge and experience levels, bidder and competitor experience, and steel estimators’ expertise are assumed as being uniform.

**Limitations** include that cost impact is calculated only for major, not minor types, due to the limited number of data points. This limitation is acknowledged, but accepted based on the careful creating and curating of data, as described in the following sections. As has been mentioned under scope, the data are from the Washington metropolitan area in the Mid-Atlantic region of the eastern U.S. Further research should apply the methodology to other geographic regions.

**Literature Review**

This literature review has two sections: How research and industry approach uncertainty with the goal of increasing design quality, and how industry, professional organizations, government, and research assign contingency to levels of increasing accuracy that available information allows.

**Design Quality and Uncertainty**

Design uncertainties are considered by these authors to mean poorly defined issues that reduce design quality. This statement is supported by Freire and Alarcón’s (2002) definition of errors and omissions as elements that affect the quality of the products in the design process. The following performance measures were proposed for said quality (Freire and Alarcón 2002, p. 250): “(1) changes in design = number of changes/total number of drawings (or documents); and
(2) errors and omissions = number of errors/total number of drawings (documents).” How much these measures relate to the quality of bid documents remains debatable, because most project participants are concerned with cost rather than the quantity of errors and changes. In contrast, this paper explores both the quantity of different error types and their impacts as contract ratios.

Lee et al. (2003) observed and analyzed three different groups of architects. Their empirical study of architects’ behaviors focused on causes of errors. In contrast, this research study is investigating design with a focus on error types that have been classified in the companion paper (Duzkale and Lucko 2015); their costly consequences are analyzed herein. Lopes and Forster (2013) concentrated on human errors in ‘Requirements Engineering of information sciences. They compiled 29 minor theoretical types of human errors into three major categories, which were (1) slips, (2) lapses, and (3) mistakes per Norman (1990) and Reason (1990). Safin et al. (2008) also adopted Reason’s (1993) classification of human errors due to designer actions in their study about errors in architectural design and detection mechanisms. But their study was limited to conceptual design only. However, it described three phases of design error control as (1) detection – cf. the companion paper (Duzkale and Lucko 2015), (2) identification – described in quantitative analysis in this research, and (3) recovery – responded by the designers via requests for information from estimators. As error recovery cannot be accomplished without both detection and identification, this current research is a vital support for estimators and designers.

Uncertainty and Contingency

Completeness of bid documents is commonly expressed in percent. Based on Liu and Zhu (2007) estimation accuracy remained at approximately 10% level over the past 40 years. This research focuses on the accuracy of cost estimates during bid preparation rather than earlier design
development phases. Love et al. (2011) cited another study that errors in contract documentation may add about 5% to its price. The interview-based study was conducted on two public school projects with cost growth of 4.4% due to errors in contract documents. The type of uncertainty in their case study was *incomplete*. Their was to include penalties or incentives in design contracts. Percent of completeness and corresponding accuracy ranges differ vastly among the empirical classifications that have been published by professional institutions. The Association for the Advancement of Cost Engineering International (AACEi), the Electric Power Research Institute (EPRI), and Department of Energy (DOE) defined contingency amounts for each pre-project and planning stage as shown in Table 1. Table 1 shows that accuracy improves from concept stage to bid document stage due to added information; hence uncertainty is reduced. AACEi suggested 5% contingency at the “Check Estimate or Bid/Tender” stage, whereas EPRI advocated 5-10% contingency. Achieving accuracy at such level of detail is the focus of this paper. Definitions per Table 1 are conflicting, as is indicated with bold italics: AACEi’s ‘Feasibility Study’ conflicts with DOE’s; AACEi’s ‘Concept Screening’ conflicts with DOE’s; AACEi’s ‘Authorization or Control’ conflicts with Blok’s; AACEi’s ‘Authorization or Control’ and ‘Control or Bid/Tender’ stages conflict with each other (same terms, different stages); AACEi’s ‘Control or Bid/Tender’ and ‘Check Estimate or Bid/Tender’ stages conflict with each other (same terms, different stages); DOE’s ‘Budget/Conceptual Design’ conflicts with Blok’s; and DOE’s ‘Title I’ and Blok’s ‘Class I’ conflict (same numerical denotation-different stages). A total of five stages were listed by AACEi, DOE, and Blok. EPRI only listed four stages. No less than 25 different terms labeled the stages, which can cause conflicts. Percentages were inconsistent between the stages by industry, government, and research. This is a major problem proving the lack of understanding of documents between different entities. Liu and Zhu (2007) provided yet another
compilation from secondary sources of 30-50%, 20%, 10%, and 5% accuracies from concept via design and bid to preconstruction stages. While percentages of Table 1 may be applied in estimating the total bid, it is unknown how realistic they are for the chosen scope of structural steel. The question of what are the impacts of the different types of uncertainties on the steel trade therefore arises. The following section outlines the methodology to answer this issue.

Methodology for Bid Document Uncertainty Analysis

As an expansion to methodology flowchart provided in Figure 1 of the companion paper, Figure 2 is methodology flowchart to amend by quantitative analysis of uncertainties that were classified in the companion paper. Inputs are shown with italic fonts, research findings are shown with bold letters.

For Research Objective 1, the next step is to perform quantity takeoffs for each data point to estimate quantities of elements that incur uncertainties. Uncertainties extracted from bid documents are explained individually. A total of 1,000 iterations to randomly pick a cost between the minimum and maximum of the cost items for each cost element assisted to take the average of the random cost inputs. Next, uncertainty ratios were calculated by finding the ratio of the cost of the uncertainty to lowest bid price of each project. Low bid numbers were available through the websites of the public school systems and through the contracts of the projects awarded to the researcher’s own company. Outputs represented with bold fonts are provided in statistical analysis of this document. Non-parametric bootstrapping with 10,000 iterations is
utilized for statistical analysis of the data. Applying the methodology to other trades in the construction industry can contribute to reducing the impact of uncertainties.

Uncertainty Data Collection

Uncertainty data were collected between August 2009 and October 2010. Figure 3 shows the breakdown of the quantity takeoff for structural steel that this research performed. Primary steel is beams, columns, joists, and decks. Quantity takeoffs for joists and decks are usually performed by suppliers and included in their quotations to the subcontractor, whose estimator checks these quantities. Secondary steel for columns are e.g. base, cap, stiffener, and connection plates, splice plates, stiffened seat elements, seat angles, deck support angles around columns at column-beam connections, and gusset plates that are welded to columns to brace members laterally. Secondary steel for beams are e.g. bottom and top plates, beam end plates, moment plates, stiffener plates, splice plates, slab edge pour stop plates, outrigger angles, braces, kicker angles, double angle connection clips, angle wall anchors, angles attached to beams, and steel channels.

The following examples are uncertainties that were actually observed in the data from structural steel drawings. Information on their initial pages included general notes for trades, design loads, trade responsibilities, material grades, testing and inspection, and lists of structural rules to be followed. Trades involved in the structural system were foundation, concrete, masonry, structural steel, lintels, decking, precast, and roofing. While general notes summarized key information about a structure, part or all of it may be repeated in other sections of the bid documents. Uncertainties in general notes were often conflicting and lack of work assignment. For example, steel angle or steel beam lintels for openings were in general notes for masonry, not...
those for metals. Information was also conflicting between general notes for trades, e.g. whether lintels are precast concrete or steel. Different materials were listed for the same element in some cases. For example, thickness and type of floor and roof decking differed between general notes, structural plans, or metal deck specification section 05300. Conflicting information will cause over- or underestimation in the metal supplier’s quotation to the steel fabrication subcontractor.

$Lack of work assignment$ may increase costs for the steel subcontractor if engineering labor hours to complete a task are unknown. A vague uncertainty was ‘as required’ notes for providing and installing deck accessories, e.g. pour stops, reinforcing channels, and ridge and valley plates. Alternatively, if plans lacked such accessory information, it could also be considered incomplete.

The actual design responsibility of a steel subcontractor may be different from specifications. If an engineer merely stated the assumptions and expected the steel contractor to determine shear studs as necessary per AISC specifications, the design responsibility was transferred. This type of uncertainty was labeled incomplete. In general, however, transfer of responsibility for testing and inspection to the subcontractor is a lack of work assignment. It creates a conflict of interest if the subcontractor later is supposed to hire and pay the inspector to inspect its own work.

A foundation plan follows the general notes as the second component of structural drawings. Data included top of footing and pier elevations to determine the length of steel columns, column piece marks that code the sizes and shapes of steel columns (usually tabular), leveling plate and column base plate sizes, anchor bolt numbers and depths, and references to column or plate schedules. Lack of work assignment and incorrect uncertainties were not found in foundation plans, but dimensional uncertainties were found. If the top of the footing elevation did not match between foundation plan and section, leaving the length and weight of columns uncertain, it was conflicting. If top of pier or pedestal elevations were not provided, the estimator had to assume
quantities. Foundation plans usually have dimensions between gridlines. If foundation and structural or architectural floor plans did not match it was conflicting. Incomplete foundation plans were resolved by assuming that the top of pier elevation matched that of the pier that was closest to the uncertain one, or the lowest top elevation of the closest pier of similar condition. Instances of when it was unclear if a footing had a pedestal, or if a footing or pier elevation was provided in round or square brackets (...) or […], or given only in notes were considered vague.

Floor plans exhibited all five major types. Illustrative examples are given in the next section.

**Bid Document Uncertainty Data Point Examples**

Uncertainty data as extracted are illustrated with one actual sample of per major type uncertainty. Sample plan drawings are used with permission of Anonymous Company A (2011), Anonymous Company B (2008), Anonymous Company C (2009), and Anonymous Company D (2008).

*Data Point 1.2:* Beam size in the floor plan of Figure 4 was W8X13. It referred to sections that noted it as W8X18. The eight-inch beam depth is the same in both floor plan and sections. The weight difference of five pounds per linear foot gave the difference in cost. This data point was classified as conflicting due to material size discrepancy between floor plan and sections.

*Data Point 2.1:* Beam size was incomplete—here fully missing—in the roof framing plan in Figure 5. The size was resolved by assuming W14X22 in analogy to sizes in neighboring bays.

*Data Point 2.2:* Steel member was represented with same line weight as walls in Figure 6, not bold lines. It was vague. It was resolved by using a stringent assumption to derive all cost.
Data Point 5.1: Spacing of beams in Figure 7 was shown as 4'-0” on center (O.C.), but the document scale at 1/8” equal to 1 foot scale showed it as 3'-0” O.C. The incorrect representation causes 8% quantity difference. It was resolved by a stringent assumption of using the scale value.

<INSERT FIGURE 7 HERE>

Data Point 3.3: Joist reinforcement detail R/S3.1 in Figure 8 assigned the responsibility for the supports for pipes to the steel subcontractor, but the next support detail H/S3.2 assigned the responsibility for the same supports to the mechanical subcontractor. It was lack of work assignment. It was resolved by a stringent assumption of including it for the steel subcontractor.

<INSERT FIGURE 8 HERE>

These illustrative and representative real-world examples complete Research Objective 1.

Cost Data

Material Cost

Material cost included steel, hardware, and finish coat costs. Steel here included the elements of the American Institute of Steel Construction (AISC) manual of steel construction per Table 2.

<INSERT TABLE 2 HERE>

Material cost was gathered from regional warehouse quotations. Such steel fabricators that sell large high tonnages and have storage capabilities can order steel directly from the mills. Cost data in this research were not directly based on mill pricing. Hardware cost was collected from current price lists in catalogs, websites, or direct quotations of the following regional steel suppliers: (1) Atlantic Bolts, Inc., (2) Fastenal Company, (3) Hilti Corporation, (4) McMaster-Carr Company, (5) Nelson Stud Welding, (6) Posner Industries, and (7) W. W. Grainger, Inc. Material finishing included preparation to accept primer and galvanized coating per the standards
for preparing metal substrates by the Society for Protective Coatings (SSPC) and the National Association of Corrosion Engineers International (NACE). Standards that were observed in the data are marked in Table 3. Labor cost for preparation and finishing was included in shop labor cost. Supplies were included in shop supplies. Standard shop primer paint was specified in MasterFormat division 5, sub-section 05 12 00; epoxy paint primer in sub-section 09 96 00. Yet cost for SSPC-SP6 commercial blast cleaning were based on a quotation from a specialty firm; thus supplies, labor, and general and administrative cost were excluded. Coating materials were:

- Standard, rust inhibitive, red/grey oxide, alkyd, lead – and chromate – free primer paint;
- Epoxy zinc – rich primer paint; and
- Hot dip galvanizing.

<INSERT TABLE 3 HERE>

### Labor Cost

Labor cost included (1) shop, (2) field, (3) direct office, and (4) indirect labor costs. Shop and office wages were derived from the April 2010 Washington-Baltimore-Northern Virginia National Compensation Survey provided by the Bureau of Labor Statistics (BLS 2010a). Field labor rates were extracted from May 2011 national industry-specific occupational employment and wage estimates (BLS 2011). Data from the Bureau of Labor Statistics’ NAICS 236000 tables were matched with the time periods when each project was built. Hourly rates were mean hourly earnings for full-time workers. Quantities of occupation labor units were based on the minimum number of units required to perform the office, fabrication, delivery, and installation activities.

Since it was passed in 1931, the cost impact of the Davis-Bacon Act (Pub.L. 71-798), which sets wage scales for federally funded projects, has been debated among owners, government
officials, and academics. In a study on applying it to school project labor cost, Bilginsoy and Philips (2000) found that inflation varies greatly and can be biased, with examples of 30-40%, 10-15%, 60%, 1-3%, 26%, 1.5-3%, 0.3-0.4%, 0.63%, 4.74%, and 26%. Furthermore, using data from 54 new elementary and secondary schools in British Columbia, their study indicated that this wage rate increases school construction costs by 16%. Field labor rates in this research thus were local rates unless wage scale regulation applied. While inflation impact of the Davis Bacon wage scale (DOL 2014) on school projects in the Washington metropolitan area may differ from 16%, this research analyzed ratios, not than dollar amounts. Wage scale regulation only applied to labor at the project jobsite. Shop and office labor rates were not controlled by this regulation.

374  
375  
376 Equipment Rental Cost

377 Rental rate data were gathered from quotations and invoices of the following rental companies: (1) Sunbelt Rentals of Virginia, (2) Hertz Equipment Rental Corporation, and (3) Dahl’s Equipment Rental, Inc. Small size tool data were more available than heavy hoisting equipment data. It was assumed that equipment was rented rather than owned. Its capacity was determined as the minimum size that was sufficient to perform the activity. Operator wages plus insurance, environmental protection fees, taxes, and fuel were included in crane rental rates. However, since the subcontractor used its own rigging crew, it was included under field labor. Light hoisting, aerial equipment, and tool rental costs did not include operator wages. Rental costs included:

384  
385  
386 • Tool rental: welder generator, core-drill, oxy-acetylene bottles, and air-scrubber.
General and Administrative Costs

Fixed (F) cost items in Table 4 cannot be assigned to specific projects, but are nonetheless incurred to run a company. In contrast, variable (V) costs are functions of performance of specific projects. Estimators thus apply an overhead factor to either direct cost or the total cost (Shelton and Brugh 2002) to allocated indirect costs. This assumption was used in this research.

Plant and office equipment fixed costs were considered in the data points by assuming that equipment life is ten years. Assuming a production availability of 100% and 2,000 hours per year in which 1,000 tons are manufactured, a production facility has a life of 20,000 hours. Facility size and capacity were assumed as constant over ten years. Thus, no expansion expense was included. Shop and office rent was obtained from accounting logs of the subcontractor. An extra 10% of rent was added to cover facility and property insurance and miscellaneous expenses.

Total rent was converted to hourly cost by dividing it by 2,000. Office equipment cost was the minimum required for a steel business. Hours of operation were based on a 50-week year by deducting 11 Federal holidays and assuming 8 hour days and 40 hour weeks. Fixed and variable utility costs were obtained by dividing the annual utility bill by the average tonnage produced.

Statistical Analysis

The non-parametric bootstrap method is utilized by sampling with replacement which is described as “the procedure where a random number generator independently selects integers … between 1 and n with probability 1/n. These integers determine which members of random sample are selected to be in the new random sample.” (Angelis and Stamelos 2000, p. 39). A
total of 92 data points were derived from nine schools. For a bootstrapped sample, sampling with replacement was performed 10,000 times. Mean, standard deviation, variance, minimum, maximum, and 95% confidence interval were calculated by major type for the contract ratio, i.e. the cost of an uncertainty divided by the total contract price of its project. Proportions of the five major types for each school were calculated individually and for the entire bootstrapped sample.

Bootstrapped confidence intervals for the proportions of major types and the total contract ratios are listed in Tables 5 and 6, respectively. Nearly 50% of occurrences were incomplete, slightly over 21% were conflicting, and slightly over 15% were of lack of work assignment type, while less than 10% of the bootstrapped sample fell into vague or incorrect. In terms of their fractional cost of the total contract, a somewhat different picture emerges, where conflicting and lack of work assignment both had a ratio of over 2%, incorrect had a ratio of 1%, and incomplete and vague had a ratio of under 1%. In other words, some major types were most common, but others were most costly. Descriptive statistics of sample size, its percentage of all samples, the mean (or proportion), the lower and upper bounds of the 95% confidence interval, and standard error are listed.

<INSERT TABLE 5 HERE>

<INSERT TABLE 6 HERE>

These relative quantities for the five major types of uncertainties fulfill Research Objective 2.

Research Results

Results of this research on major and minor uncertainties are summarized as follows:

- Per Table 5, major types in the bootstrapped sample by occurrence rank 49.62% incomplete, 21.41% conflicting, 15.36% lack of work assignment, 8.12% incorrect, and 5.49% vague;
Per Table 6, major types by cost impact rank conflicting the highest with 2.16% mean contract ratio. Lack of work assignment was slightly lower with 2.09%, followed by incorrect with 1.00%, incomplete with 0.87%, and vague with 0.54%. Note that the rank orders differ;

- The sum of uncertainty for contract ratios (6.66%) only slightly exceeds AACEi’s (2011) suggested contingency of 5% at the bid stage of accuracy (-3% low to +15% high) based on the contract value and Blok’s (1982) range of 5% per Table 1. The sum of uncertainty for contract ratios is within the limits of the EPRI (Rothwell 2004) contingency range of 5-10% at Finalized Estimate Stage. This validates the significance of the calculated results of the statistical analysis;

- An analysis of governing actions and precedence rules from actual bid documents, codes, standard contract, and law revealed a staggering amount of inconsistency within and between each of these official sources in terms of how they prescribe that uncertainties should be handled.

The hypothesis for the bid document uncertainty section is accepted based on the following analysis: At the 95% confidence level, a two-tailed t-test of Table 6 finds statistically significant differences between means of contract ratios between the ranked pairs conflicting–lack of work assignment, lack of work assignment–incorrect, incorrect–incomplete, and incomplete–vague.

This comparison against actual contingency recommendations fulfills Research Objective 3.

Contributions to the Body of Knowledge

This study fills the gap in the body of knowledge that estimators face when being under frequent pressure of either being the lowest bidder but losing profit or being a higher bidder and losing the bid due to uncertainty in quantity takeoff and a lack of guidance in how to assess and resolve it.

Three contributions to the body of knowledge have been made; following a newly developed description of outcomes of the companion paper (Duzkale and Lucko 2015) in form of a set
theory representation for major uncertainty types, (1) representative examples of uncertainties from real-world bid documents have been extracted for each major type; (2) the relative occurrence and cost significance of major types has been statistically analyzed to increase estimators’ awareness when faced with uncertainties. Data for the statistical analysis have been obtained via detailed and careful quantity takeoff from real-world bid documents of school projects. The diverse range of uncertainty types that has been identified in the companion paper (Duzkale and Lucko 2015) and the potential impact underline the relevance of this research. A ranking of the major types in the taxonomy based on occurrence and cost significance has been provided; and (3) said cost significance has been compared with contingency percentages that various professional organizations, government agencies, and researchers currently recommend. Together, these items allow estimators to begin moving from empirical (and thus subjective and potentially inaccurate) contingency to a quantitative approach. It is acknowledged that a research limitation is that data have been limited to the Washington metropolitan region; further studies should apply the general approach that is described herein to various other geographic regions.

Benefits of this research in addition to those presented in the companion paper include:

- Quality of bid documents could be quantified based on occurrences and types of uncertainty;
- Increased quality in bid document preparation could diminish the adverse cost impacts;
- Bidders who use a quantitative approach to determine contingency could win more projects;
- Project owners would have less financial pressure from unexpected cost due to uncertainties;
- Cost of construction could become lower if subcontractor contingency in the bid is reduced;
- Cost of the construction would be closer to the pre-bid budget on which financing was based.
Recommendations for Future Research

Bid documents of school projects with structural steel framing have been obtained from public owners and designers as mentioned in the scope. Data included cost impacts of uncertainties that are related to structural steel in bid preparation. Yet types and impacts of uncertainties related to other construction trades are worthy of future research to improve the quality of bid documents, to improve the accuracy of bids, and to lower cost. Corrections to bid documents in any addenda that may have been issued by designers after the bid opening date or during construction have been excluded; therefore future research should analyze addenda, contents of changes, and costs to better understand how project participants are dealing with uncertainties that were undetected or unresolved until it was ‘too late’. All changes to design that were included in the addenda and issued before the bid date were included in the data. Of course, prevention should be favored over seeking a cure. In conjunction with this question, the growth of uncertainty costs during the project execution should be explored to better quantify the financial value of seeking early uncertainty avoidance. This research shown that a prediction model to determine contingency accurately based on project specific factors is urgently needed. The methodology and results of this study and its companion paper (Duzkale and Lucko 2015) are general in nature and can easily be applied to other sectors in the construction industry, needing only little modification.

Moreover, it would be worthwhile to survey estimators regarding risk seeking or avoidance to discover what assumptions they currently employ to determine contingency and to what extent it is linked with the quality of design documents. Furthermore, it should be investigated how the unfortunate reality of multiple contradicting approaches in law, codes, and bid documents to resolving conflicting information can be overcome with unambiguous guidance for all scenarios.
This research is a key step towards improvement of the bid documents for increased accuracy of structural steel estimates by investigation of uncertainties in the bid documents. The primary goal of the research was to reduce uncertainties in bid preparation for structural steel. Finding, classifying, and measuring uncertainty has added vital knowledge to the construction industry for increasing the bid agents’ cognizance of the uncertainties from a steel estimator’s perspective. In practice, this research sensitizes to the issue with hard statistical data instead of empirical rules of thumb. Its quantitative approach can inform steel estimators within the geographic region of this study on how to attempt to remedy an uncertainty if clarifying information cannot be obtained, and how to best set a contingency if they incur one of the major types of uncertainties.

References


Table 1: Types of Cost Estimates (Adapted from AACEi 2011, p. 2 and DOE 2011, p. 15, p. 56; EPRI 1993 as cited by Rothwell 2004, p. 1; DOE 1997, p. 4-13; and Blok 1982)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Expected Accuracy</th>
<th>Contingency</th>
<th>Stage</th>
<th>Contingency</th>
<th>Purpose</th>
<th>Probable Error Range</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept</td>
<td>Low: -20 to -50</td>
<td>50</td>
<td>NA</td>
<td>NA</td>
<td>Planning/Feasibility</td>
<td>-40 to +40</td>
<td>Order of V</td>
</tr>
<tr>
<td></td>
<td>Screening High: +30 to +100</td>
<td>NA</td>
<td>NA</td>
<td>or Order of Magnitude</td>
<td>V</td>
<td>±25 to</td>
<td>Feasibility</td>
</tr>
<tr>
<td>Feasibility</td>
<td>Low: -15 to -30</td>
<td>30</td>
<td>Simplified</td>
<td>30-50</td>
<td>Budget/Conceptual</td>
<td>-30 to +30</td>
<td>Factor</td>
</tr>
<tr>
<td>Study</td>
<td>High: +20 to +50</td>
<td>30-50</td>
<td>Estimate</td>
<td>Design</td>
<td>IV</td>
<td>+30</td>
<td>Estimate 25%</td>
</tr>
<tr>
<td>Authorization</td>
<td>Low: -10 to -20</td>
<td>20</td>
<td>Preliminary</td>
<td>15-30</td>
<td>Title I</td>
<td>-20 to +20</td>
<td>III Estimate 15%</td>
</tr>
<tr>
<td>or Control</td>
<td>High: +10 to +30</td>
<td>15-30</td>
<td>Estimate</td>
<td>15-30</td>
<td>Title I</td>
<td>+20</td>
<td>Estimate 15%</td>
</tr>
<tr>
<td></td>
<td>Low: -5 to -15</td>
<td>15</td>
<td>Detailed</td>
<td>10-20</td>
<td>Title II</td>
<td>-5 to +5</td>
<td>II Definitive</td>
</tr>
<tr>
<td>Bid/Tender</td>
<td>High: +5 to +20</td>
<td>10-20</td>
<td>Estimate</td>
<td>10-20</td>
<td>Title II</td>
<td>+15</td>
<td>Estimate 10%</td>
</tr>
<tr>
<td></td>
<td>Low: -3 to -10</td>
<td>5</td>
<td>Finalized</td>
<td>5-10</td>
<td>Construction</td>
<td>-5 to +5</td>
<td>I Final</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>Final</td>
<td>5-10</td>
<td>Construction</td>
<td>+5%</td>
<td>Final Cost Data</td>
</tr>
</tbody>
</table>

Note: Class, Stage, and Purpose are abbreviations used for categorization purposes.
<table>
<thead>
<tr>
<th>Estimate</th>
<th>Estimate</th>
<th>+10</th>
<th>Estimate</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>or</td>
<td>High:</td>
<td>+3</td>
<td>to</td>
<td>+15</td>
</tr>
</tbody>
</table>

*Bid/Tender*

Note: *Bold italics* are discrepancies.
<table>
<thead>
<tr>
<th>Element</th>
<th>AISC</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchor bolts for structural steel</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Base plates and bearing plates</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Beams, Girders, Trusses, Bracing, Columns, Posts</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Shop and Field Connection materials for framing</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Floor plates attached to steel frame</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Grillage beams and girders</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Hangers essential to the structural steel frame</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Leveling plates, wedges, shims, and leveling screws</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Marquee or canopy framing</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Plate attached to the structural frame</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Roof frames of standard structural shapes</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Shear connectors - if specified shop attached</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Struts and forming part of the structural frame</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Cables for permanent bracing or suspension systems</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Embedded steel in precast or poured concrete</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Steel grating, Metal Deck</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Structural steel at stairs and landings</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Stainless steel shapes</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Shear connectors field installed</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Catwalk framing</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Description</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>Epoxy chemical anchors and Expansion anchors</td>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Sleeves and stiffeners for pass thru piping</td>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Lintels, if attached to the structural steel frame</td>
<td>Y</td>
<td></td>
</tr>
</tbody>
</table>
Table 3: Steel Surface Preparation Standards (adapted from Sherwin-Williams 2012)

<table>
<thead>
<tr>
<th>Preparation Standard</th>
<th>Description</th>
<th>Steel</th>
<th>Galvanized</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSPC – SP1</td>
<td>Solvent Cleaning</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>SSPC – SP2</td>
<td>Hand Tool Cleaning</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>SSPC – SP3</td>
<td>Power Tool Cleaning (PTC)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>SSPC – SP11</td>
<td>PTC to Bare Metal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSPC – SP7 / NACE 4</td>
<td>Brush – Off Blast Cleaning</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>SSPC – SP14 / NACE 8</td>
<td>Industrial Blast Cleaning</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>SSPC – SP6 / NACE 3</td>
<td>Commercial Blast Cleaning</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>SSPC – SP10 / NACE 2</td>
<td>Near White Blast Cleaning</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>SSPC – SP5 / NACE 1</td>
<td>White Metal Blast Cleaning</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
### Table 4: General and Administrative Costs

<table>
<thead>
<tr>
<th>Facility (F/V)</th>
<th>Professional (F)</th>
<th>Office (F/V)</th>
<th>Miscellaneous (F/V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rent (F)</td>
<td>Accounting (F)</td>
<td>Supplies (V)</td>
<td>Advertisement (F)</td>
</tr>
<tr>
<td>Utilities (F/V)</td>
<td>Estimating (F)</td>
<td>Salary (V)</td>
<td>Subscriptions (F)</td>
</tr>
<tr>
<td>Maintenance (V)</td>
<td>Legal (F)</td>
<td>Furniture (F/V)</td>
<td>AISC Fee (V)</td>
</tr>
<tr>
<td>Property Tax (F)</td>
<td>Network (F)</td>
<td>Software (V)</td>
<td>Licenses (F)</td>
</tr>
<tr>
<td>Major Uncertainty</td>
<td>N</td>
<td>Mean</td>
<td>Lower 95% CI</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------</td>
<td>-------</td>
<td>--------------</td>
</tr>
<tr>
<td>Conflicting</td>
<td>19,265</td>
<td>21.41%</td>
<td>21.1%</td>
</tr>
<tr>
<td>Incomplete</td>
<td>44,661</td>
<td>49.62%</td>
<td>49.3%</td>
</tr>
<tr>
<td>Vague</td>
<td>4,944</td>
<td>5.49%</td>
<td>05.3%</td>
</tr>
<tr>
<td>Incorrect</td>
<td>7,304</td>
<td>8.12%</td>
<td>07.9%</td>
</tr>
<tr>
<td>Lack of Work Assignment</td>
<td>13,826</td>
<td>15.36%</td>
<td>15.1%</td>
</tr>
</tbody>
</table>
### Table 6: Bootstrapped Confidence Intervals: Total Contract Ratio

<table>
<thead>
<tr>
<th>Major Uncertainty</th>
<th>N</th>
<th>Mean</th>
<th>Lower 95% CI</th>
<th>Upper 95% CI</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conflicting</td>
<td>19,265</td>
<td>2.16%</td>
<td>2.10%</td>
<td>2.21%</td>
<td>0.029%</td>
</tr>
<tr>
<td>Incomplete</td>
<td>44,661</td>
<td>0.87%</td>
<td>0.86%</td>
<td>0.89%</td>
<td>0.006%</td>
</tr>
<tr>
<td>Vague</td>
<td>4,944</td>
<td>0.54%</td>
<td>0.52%</td>
<td>0.55%</td>
<td>0.008%</td>
</tr>
<tr>
<td>Incorrect</td>
<td>7,304</td>
<td>1.00%</td>
<td>0.98%</td>
<td>1.03%</td>
<td>0.012%</td>
</tr>
<tr>
<td>Lack of Work Assignment</td>
<td>13,826</td>
<td>2.09%</td>
<td>2.02%</td>
<td>2.15%</td>
<td>0.034%</td>
</tr>
</tbody>
</table>
Figure 1: Set Theory Representation of Major Uncertainty Types

(a): Conflicting

(b): a = a₁ + a₂; C = 0
a₁⊂a ⇒ a₁⊂A and a₂⊂A′
and analogous for s

(c): Vague

(d): Incorrect

Figure 1: Set Theory Representation of Major Uncertainty Types
Figure 2: Flowchart of Bid Document Uncertainty Analysis

- Documents from Owner / Designer
- Comparing Information Sources
  - AISC Manual Database
- Plan Comparison Layers
- Create Uncertainty Database
- Detail Comparison Layers
- Structural
  - Architectural
  - Supplemental
  - General Notes
- Data Points
- Analysis of Minor Uncertainties
  - Uncertainty Classification (I)
  - Uncertainty Framework (I)
- Assignment of Classifications
- Perform Quantity Takeoff for Each Minor Uncertainty
- Estimate Cost Data Point
- Calculate Error per Contract Ratio per School Project
- Average Costs 1,000 Iterations
- Non-Parametric Bootstrapping of Data with 10,000 Replacements
- Conflicting Percent
  (Table 5)
- Incomplete Percent
  (Table 5)
- Vague Percent
  (Table 5)
- Incorrect Percent
  (Table 5)
- Lack of Assignment Percent
  (Table 5)
- Contract Ratios (Cost Significance) of Major Types
  (Table 6)
Figure 3: Data Collection Flowchart

Review Bid Documents

Material Quantity Takeoff

Primary Steel Quantity
Steel beams and column data from foundation, floor, roof plans and column schedules

Design Intent
Floor beam
Canopy
Equipment supports

Fabrication
Camber
Slope
Taper
Rolling

Shape
Tubing
Wide flange
Channel
Plate girder

Finish
Unprimed
Galvanized
Standard
Special

Erection
Cantilever
Size
Slope
Connection

Secondary Steel Quantity
Hardware and connection elements from specifications and sections

Shape
Tubing
Angle
Channel
Plate girder

Fabrication
Notch
Eased edge
Taper
Rolling

Design Intent
Supp. others
Connection
Supp. self

Figure 3: Data Collection Flowchart
Figure 4: Plan View of Floor Framing and Sections (With permission by Anonymous Company A 2011)
Figure 5: Plan View of Structural Roof Framing (With permission by Anonymous Company B 2008)
(a) Plan View

(b): Finished Product

Figure 6: Structural Canopy Framing

(a: With permission by Anonymous Company B 2008 and b: photo by first author 2009)
Figure 7: Structural Roof Framing

(a): Plan View  (b) Measured with Scale

(a: With permission by Anonymous Company C 2009 and b: photo by first author 2011)
Figure 8: Joist Reinforcement Detail (With permission by Anonymous Company D 2008)
**Figure and Table Captions**

Figure 1: Set Theory Representation of Major Uncertainty Types

Figure 2: Flowchart of Bid Document Uncertainty Analysis

Figure 3: Data Collection Flowchart

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(a) Plan View

(b) Finished Product

Figure 7: Structural Roof Framing (a: With permission by Anonymous Company C 2009 and b: photo by first author 2011)

(a) Plan View

(b) Measured with Scale

Figure 8: Joist Reinforcement Detail (With permission by Anonymous Company D 2008)

Table 1: Types of Cost Estimates (Adapted from AACEi 2011, p. 2 and DOE 2011, p. 15, p. 56; EPRI 1993 as cited by Rothwell 2004, p. 1; DOE 1997, p. 4-13; and Blok 1982)

Table 2: Scope of Structural Steel Identified in Data

Table 3: Steel Surface Preparation Standards (Adapted from Sherwin-Williams 2012)

Table 4: General and Administrative Costs
Table 5: Bootstrapped Confidence Intervals: Major Type Proportion

Table 6: Bootstrapped Confidence Intervals: Total Contract Ratio
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**Supplemental Data File**

I. Conceptual Framework and - REWORKED 09-28 GL - FINAL - WATERMARK.doc
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Principal Investigator: Dr. Gunnar Lucko, Catholic University of America
Graduate Researcher: Mr. Abdulhamit Kayihan Duzkale (ID 2187829).

RE: Partial use of design documents for academic research purpose

Date: 2-13-2013

Architect Name: SAMAH ASSOCIATES, PC
Architect Address: 10521 Rosehaven Street Suite 200
Fairfax, VA 22030

Project Name(s): George C. Marshall High School

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KENNETH CARON, AIA
PROJECT MANAGER  

Signature  

Date and Location

Name and Title
Dear Sir or Madam,

I am writing to you to respectfully ask for your kind support of the doctoral dissertation research of my graduate student Mr. Abdulhamit Kayihan Duzkale (ID 2187829). His research seeks to reduce uncertainties in the bidding phase of structural steel buildings by identifying such types of uncertainty and quantifying them in a partial take-off and pricing that he will perform manually. No CAD files are needed, simple paper copies of the plan drawings or PDF files fully suffice.

Please allow him to use your project bidding documents by signing the attached data permission form. As stated on the form, your documents will be strictly used only for this research project. Any resulting presentations or publications will be intended to an academic audience and will fully anonymize your project’s name, location, and all participants to ensure confidentiality.

Performing this analysis is anticipated to yield several benefits for the U.S. construction industry:

1. The quality of design and bidding documents can be improved.
2. Minimizing the uncertainties will increase the accuracy of bids.
3. New insights into cost impacts of uncertainties in design documents.
4. Less number of RFI’s will be generated by bidders before the bid.
5. This will lead to time savings in design and in answering bidders’ RFIs.
6. Additional time savings in change order review due to uncertainties.
7. Minimizing number of bidder assumptions when time is of the essence.
8. Less number of disputes and conflicts due to design uncertainties.
9. More accurate subcontract prices that are more in line with real costs.
10. Less financial pressure on owner from reducing any unexpected costs.

I am grateful for your support of this important project. Please do not hesitate to contact me at lucko@cua.edu if you have any questions or feedback.

Very sincerely yours,

[Signature]

Gunnar Lucko, Ph.D.
Assistant Professor and Director
DATA PERMISSION FORM

Principal Investigator: Dr. Gunnar Lucko, Catholic University of America
Graduate Researcher: Mr. Abdulhamit Kayihan Duzkale (ID 2187829).

RE: Partial use of design documents for academic research purpose

Date: 18 October, 2012

Owner Name: Architect: cox graae + spack architects

Owner Address: Architect: 2909 M Street, NW Washington DC 20007

Project Name(s): Reed School / Westover Library

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William Spack, AIA - Principal

Name and Title Signature

10.18.12 - Washington DC Date and Location
Date: 10/23/12

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Number of Pages Including Cover Sheet: 02

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Phone: 202-612-0872

Company: Hitite Inc.

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DATA PERMISSION FORM

Principal Investigator: Dr. Gunnar Lucko, Catholic University of America
Graduate Researcher: Mr. Abdulhamit Kayihan Duzkale (ID 2187829).

RE: Partial use of design documents for academic research purpose

Date: 10/23/2012

Owner Name: MGV Consulting Structural Engineers, Inc.
Owner Address: 6239 Executive Blvd.
Rockville, MD 20852

Project Name(s): Wheatly Elem. School

1211 Neal St., NE.
Washington, DC

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Principal ___________________________ Signature ___________________________
Name and Title ___________________________ Date and Location 10/23/12 MGV
DATA PERMISSION FORM

Principal Investigator: Dr. Gunnar Lucko, Catholic University of America
Graduate Researcher: Mr. Abdulhamit Kayihan Duzkale (ID 2187829).

RE: Partial use of design documents for academic research purpose

Date: 6/27/12

Owner Name: CUMBERLAND COUNTY PUBLIC SCHOOLS
Owner Address: 125 N. COURT ST.
WESTMINSTER, MD
21157

Project Name(s): WESTMINSTER HIGH SCHOOL
B2 FAC PROJECT

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[Signature]

Name and Title

Date and Location
THE CATHOLIC UNIVERSITY OF AMERICA
DEPARTMENT OF CIVIL ENGINEERING
CONSTRUCTION ENGINEERING AND MANAGEMENT PROGRAM

620 Michigan Avenue NE
Washington, DC 20064
Tel: (202) 319-5163, Fax: (202) 319-6677

May 26, 2011

Dear Sir or Madam,

I am writing to you to respectfully ask for your kind support of the doctoral dissertation research of my graduate student Mr. Abdulhamit Kayihan Duzkale (ID 2187829). His research seeks to reduce uncertainties in the bidding phase of structural steel buildings by identifying such types of uncertainty and quantifying them in a partial take-off and pricing that he will perform manually. No CAD files are needed, simple paper copies of the plan drawings or PDF files fully suffice.

Please allow him to use your project bidding documents by signing the attached data permission form. As stated on the form, your documents will be strictly used only for this research project. Any resulting presentations or publications will be intended to an academic audience and will fully anonymize your project’s name, location, and all participants to ensure confidentiality.

Performing this analysis is anticipated to yield several benefits for the U.S. construction industry:

1. The quality of design and bidding documents can be improved.
2. Minimizing the uncertainties will increase the accuracy of bids.
3. New insights into cost impacts of uncertainties in design documents.
4. Less number of RFI’s will be generated by bidders before the bid.
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6. Additional time savings in change order review due to uncertainties.
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8. Less number of disputes and conflicts due to design uncertainties.
9. More accurate subcontract prices that are more in line with real costs.
10. Less financial pressure on owner from reducing any unexpected costs.

I am grateful for your support of this important project. Please do not hesitate to contact me at lucko@cua.edu if you have any questions or feedback.

Very sincerely yours,

[Signature]

Gunmar Lucko, Ph.D.
Assistant Professor and Director
ASCE Authorship, Originality, and Copyright Transfer Agreement

Publication Title: Journal of Construction Engineering and Management

Manuscript Title: Exposing Uncertainty in Bid Preparation of Steel Construction Cost Estimating: II. Comparative Analysis and Quantitative C-I-V-I-I Classification

Author(s) – Names, postal addresses, and e-mail addresses of all authors

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Dr. Gunnar Lucko, Department of Civil Engineering, 620 Michigan Avenue NE, Washington, DC 20064, lucko@cua.edu

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Dr. Gunnar Lucko

Signature Date

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Dr. Gunnar Lucko

Signature Date

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Dr. Gunnar Lucko

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Date: [2011-07-28]

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Thank you, done.

Acronyms. Acronyms, abbreviaations, and uncommon units must be spelled out at first appearance in the text.
The authors have checked the entire manuscript and added the missing meaning of AISC upon first use, which now reads:

Fabrication and erection of structural steel are assumed to be performed in accordance with current American Institute of Steel Construction (AISC) Code of Standard Practice (2005) guidelines.

The journal is requiring a clear explanation of the primary contributions this research makes to the Body of Knowledge. These claims need to be present in the Abstract and Conclusion of the manuscript and function as a summary of the unique value the work contributes to the construction engineering and management global community. Are these statements present in the manuscript? Yes/No.
Reviewer #1: Yes
Reviewer #2: Yes

Thank you for this positive assessment.

Does the manuscript present a specific, easily identifiable advance in knowledge? Is it applicable and useful to the profession?
Reviewer #1: The contributions to the body of new knowledge need to be modified. The construction professionals have been dealing with the uncertainty and contingency for many years. I don't think that the knowledge presented in the paper will have much impact on industry practices.

Thank you, the authors have modified the contributions statement somewhat. They respectfully uphold the tenets of their contribution. Among the authors is an industry professional, who has practiced since 1998 and since 2007 directs a steel manufacturing, supplying, and installing firm. This first hand experience indicates that industry practice appears to be purely empirical and highly dependent on the individual estimators’ assumptions. This should be replaced with a quantitative approach. Having this delineation not just of uncertainty types, but of their actual impact can lead to improved estimates and better chances of winning projects.

This study fills the gap in the body of knowledge that estimators face when being under frequent pressure of either being the lowest bidder but losing profit or being a higher bidder and losing the bid due to uncertainty in quantity takeoff and a lack of guidance in how to assess and resolve it.

Three contributions to the body of knowledge have been made; following a newly developed description of outcomes of the companion paper (Duzkale and Lucko 2015) in form of a set theory representation for major uncertainty types, (1) representative examples of uncertainties from real-world bid documents have been extracted for each major type; (2) the relative occurrence and cost significance of major types has been statistically analyzed to increase estimators’ awareness when faced with uncertainties. Data for the statistical analysis have been obtained via detailed and careful quantity takeoff from real-world bid documents of school projects. The diverse range of uncertainty types that has been identified in the companion paper (Duzkale and Lucko 2015) and the potential impact underline the relevance of this research. A ranking of the major types in the taxonomy based on occurrence and cost significance has been provided; and (3) said cost significance has been compared with contingency percentages that various professional organizations, government agencies, and researchers currently recommend. Together, these items allow estimators to begin moving from empirical (and thus subjective and
potentially inaccurate) contingency to a quantitative approach. It is acknowledged that a research limitation is that data have been limited to the Washington metropolitan region; further studies should apply the general approach that is described herein to various other geographic regions.

Benefits of this research in addition to those presented in the companion paper include:
• Quality of bid documents could be quantified based on occurrences and types of uncertainty;
• Increased quality in bid document preparation could diminish the adverse cost impacts;
• Bidders who use a quantitative approach to determine contingency could win more projects;
• Project owners would have less financial pressure from unexpected cost due to uncertainties;
• Cost of construction could become lower if subcontractor contingency in the bid is reduced;
• Cost of the construction would be closer to the pre-bid budget on which financing was based.

Reviewer #2: Yes. Its contribution is agreeable, as specified by the authors.

Thank you for this positive assessment.

Has the information already been published elsewhere, either wholly or in part?
Reviewer #1: No
Reviewer #2: No

Thank you for this positive assessment.

Is the subject matter within the scope of the journal? Or is it better suited to another journal?
Reviewer #1: Yes.
Reviewer #2: Yes

Thank you for this positive assessment.

Do the title and abstract accurately describe the contents? Does the abstract include all of the main findings of the study?
Reviewer #1: (No Response)
Reviewer #2: Yes

Thank you for this positive assessment.

Is the review of literature limited to that framing the new knowledge? Are all references pertinent and complete?
Reviewer #1: (No Response)
Reviewer #2: More literature review on design errors is suggested. See the detailed comment.

Thank you, see response to detailed comments.

Is the methodology sufficiently well explained that someone else knowledgeable about the field could repeat the study?
Reviewer #1: (No Response)
Reviewer #2: Overall OK, but more explanation is needed on the 95 data points used for the bootstrap.
Thank you, the authors have added some additional information about the 95 data points to the extent that the rather strict confidentiality agreements with the data sources, who enabled this research, allow. The respective extended section now reads as follows:

The scope of this research specifically includes cost and impact of the design uncertainties within the bid documents for structural steel framing. The exemplary data that are selected for this research are public school projects from the Washington metropolitan area (consisting of Washington, DC, Northern Virginia, and Maryland), which contain substantial amounts of structural steel. Besides, they feature a uniform design and their data are readily accessible from the public owners of the respective school systems. Three of the nine school projects in the data were located in each state for an even coverage. The substantial amounts of plan drawing and specification pages that have been analyzed per project are listed in Table 2 of the companion paper (Duzkale and Lucko 2015). These school projects have similar structural design characteristics. Each project design had structural steel framing that consisted of steel beams and columns plus steel joists on load-bearing masonry walls. The design loads and the overall geometry of the structures were similar due to close geographical proximity of the projects and typical functional requirements for the intended users. The word ‘plan’ in this research study will mean all of the design drawings, which can be elevations and sectional, detail, and top views.

Are the results soundly interpreted and related to existing knowledge on the topic?
Reviewer #1: (No Response)
Reviewer #2: They look appropriate.

Thank you for this positive assessment.

Are the conclusions sound and justified? Do they follow logically from data presented?
Reviewer #1: (No Response)
Reviewer #2: Some limitations of the study need to be explained. See the detailed comments.

Thank you, see response to detailed comments.

Do all elements of the manuscript relate logically to the study's statement of purpose?
Reviewer #1: (No Response)
Reviewer #2: Yes

Thank you for this positive assessment.

Can the paper be shortened without compromising its message? Is each figure and table necessary to the understanding of the conclusions? Can any be omitted without compromising the paper's message?
Reviewer #1: (No Response)
Reviewer #2: They look appropriate.

Thank you for this positive assessment.

Editor: This manuscript is a well organized paper with archival value in it. The two reviewers have provided constructive comments that the authors may need to carefully address and incorporate into their revised manuscript or rebut with logical justification. The authors need to attach a complete response table to clearly show how each comment has been addressed in the revision.
Reviewer #1: The authors studied the impact of uncertainties that contributed to the bid contingency amount in structural steel framing of the selected school projects in Washington D.C. metropolitan area. The reviewer has the following suggestions for the authors to improve their manuscript.

1. On pages 4 and 5, the authors mentioned research question, sub-questions, and hypothesis. However, there was no test of hypothesis described in the manuscript. What the authors did were to address the research objectives 1 and 3. There was a disconnection between the hypothesis and objectives. Therefore, there is a logical problem in the manuscript that the authors need to address.

Thank you, the authors have clarified the text that the hypothesis is actually tested statistically and accepted, because significant differences are found between all pairs (ranked by value). In addition, the values are within a comparable magnitude as the empirical ones (which are not grounded in any known data), which gives further credibility and improves the confidence that steel estimators can have in using the research results to derive their contingency. The authors have added a clear statement of the statistical analysis, which now reads as follows:

*The hypothesis for the bid document uncertainty section is accepted based on the following analysis: At the 95% confidence level, a two-tailed t-test of Table 6 finds statistically significant differences between means of contract ratios between the ranked pairs conflicting–lack of work assignment, lack of work assignment–incorrect, incorrect–incomplete, and incomplete–vague.*

2. The authors mentioned that three contribution to the body of knowledge have been made. The reviewer believes that the first contribution "representative examples of uncertainties from real-world bid documents have been extracted for each major type" is well known in the industry. People may disagree on certain items, which does not mean the body of knowledge is not there.

Thank you, the authors are acutely aware of the need to disseminate the research to practitioners. Since the rigorous taxonomy and framework of the companion paper may not be studied by all readers in detail, the authors feel a need to provide an easy access for this intended audience, so that they can benefit from the research as soon as possible. Since as the reviewer correctly says that terminology can be misunderstood, selecting and providing illustrative representative examples forms part of the methodology and indeed is valuable contribution in the author’s view. The objective has been rephrased to emphasize this purpose and now reads as follows:

*In the context of a case study, define and illustrate the major uncertainty types that have been defined based on the taxonomy and explained with the taxonomy of the companion paper with representative samples from the data set. This will aid in a rapid dissemination by enabling practitioners to unambiguously understand these types and implement the key results of this research in preparing their steel estimates;*

3. Because data were collected from a particular location, Washington D.C., therefore, the statistical analysis outcomes may be significantly different using data from other locations. As a result, the contributions to the body of knowledge 2 and 3 may diminish. The authors need to acknowledge this in the paper.

Another suggestion to increase the value of this paper is that the authors may need to investigate if a mathematical model (prediction model) between uncertainty and contingency can be developed using the collected data.
Thank you, the authors have added this acknowledgement into the limitation section and into the contributions section to remind the reader of this initially disclosed aspect of the methodology:

The scope of this research specifically includes cost and impact of the design uncertainties within the bid documents for structural steel framing. The exemplary data that are selected for this research are public school projects from the Washington metropolitan area (consisting of Washington, DC, Northern Virginia, and Maryland), which contain substantial amounts of structural steel. Besides, they feature a uniform design and their data are readily accessible from the public owners of the respective school systems.

Limitations include that cost impact is calculated only for major, not minor types, due to the limited number of data points. This limitation is acknowledged, but accepted based on the careful creating and curating of data, as described in the following sections. As has been mentioned under scope, the data are from the Washington metropolitan area in the Mid-Atlantic region of the eastern U.S. Further research should apply the methodology to other geographic regions.

A ranking of the major types in the taxonomy based on occurrence and cost significance has been provided; and (3) said cost significance has been compared with contingency percentages that various professional organizations, government agencies, and researchers currently recommend. It is acknowledged that a research limitation is that data have been limited to the Washington metropolitan region; further studies should apply the general approach that is described herein to various other geographic regions.

They also checked the companion paper, where this is already stated in the respective section: Limitations include that data are drawn from institutional projects in the Washington region only. While it cannot be guaranteed that the taxonomy of this exploratory study can be equally applied to all types of construction, every effort has been made to capture the most uncertainty types, supported by the first author’s 15 years of professional experience in structural steel estimating with an average of 12 bids per month. It is hoped that future research will expand and refine the framework and taxonomy that is presented in this research study with a larger set of bid data for a wider geographical coverage and also for other sectors in the construction industry.

Thank you for the interesting idea, which will need to be addressed in future research for a third paper and has accordingly been added as an urgent recommendation for further work: Of course, prevention should be favored over seeking a cure. In conjunction with this question, the growth of uncertainty costs during the project execution should be explored to better quantify the financial value of seeking early uncertainty avoidance. This research shown that a prediction model to determine contingency accurately based on project specific factors is urgently needed. The methodology and results of this study and its companion paper (Duzkale and Lucko 2015) are general in nature and can easily be applied to other sectors in the construction industry, needing only little modification.

Reviewer #2: The objectives of this study are to categorize the design-related uncertainties that estimators may face during the bidding of steel construction, and to statistically analyze the relative occurrence and cost significance. In general the paper is well-structured and interesting.
with significant findings based on real school projects. The study can be of value to not only the academia but also the industry. Below are improvement suggestions that I hope the authors can address.

Some major comments are as follows:
1) I understand there is a companion paper that provides uncertainty taxonomy in a greater detail. However, it is still suggested to provide more explanation about what Figure 1 means for readers understanding.

Thank you for this positive assessment.

The authors are grateful and encouraged by the positive feedback and information from the editor. They apologize to the involved reviewers for the confusion that the unintentional split of these companion papers due to their two submittal types – which the authors assumed would be reviewed jointly – caused the reviewers. To facilitate the review, they provide the respective companion paper as an appendix to this submittal. Various cross-references have been added to both papers at useful points in their texts.

2) There have been a number of studies aimed at investigating design errors, yet the authors included only one study in Section 7.1. Expanding the section with more literature is suggested. A few studies that may be of interest to the authors are listed below:

Thank you kindly, the authors have added these valuable sources plus several more to their literature review section on design errors, which in its extended form now reads as follows:

Lee et al. (2003) observed and analyzed three different groups of architects. Their empirical study of architects’ behaviors focused on causes of errors. In contrast, this research study is investigating design with a focus on error types that have been classified in the companion paper (Duzkale and Lucko 2015); their costly consequences are analyzed herein. Lopes and Forster (2013) concentrated on human errors in ‘Requirements Engineering of information sciences. They compiled 29 minor theoretical types of human errors into three major categories, which were (1) slips, (2) lapses, and (3) mistakes per Norman (1990) and Reason (1990). Safin et al. (2008) also adopted Reason’s (1993) classification of human errors due to designer actions in their study about errors in architectural design and detection mechanisms. But their study was limited to conceptual design only. However, it described three phases of design error control as (1) detection – cf. the companion paper (Duzkale and Lucko 2015), (2) identification – described in quantitative analysis in this research, and (3) recovery – responded by the designers via requests for information from estimators. As error recovery cannot be accomplished without both detection and identification, this current research is a vital support for estimators and designers.

Love et al. (2011) cited another study that errors in contract documentation may add about 5% to its price. The interview-based study was conducted on two public school projects with cost growth of 4.4% due to errors in contract documents. The type of uncertainty in their case study
was incomplete. Their was to include penalties or incentives in design contracts.

3) The 92 data points (Line 485) need to be explained in greater detail.

4) Some of the statements in Section 13 seem to reveal the (significant) limitations of the study, as follows.

a. The authors state that the addenda were not included in the analysis. When estimators bid a job, addenda are one of the most important items that they care about, because in general the owner use addenda to fix (a significant amount of) design errors and provide more clarifications. So, if the addenda were not considered for the analysis, it is hard to say that Table 5 and Table 6 were based on conventional industry bidding practices that significantly use addenda for bidding purpose. How can the authors justify the exclusion of the addenda? Why were they excluded? Please clarify this limitation as to if and how the exclusion of the addenda can possibly make the study results biased. In addition, the validation of Table 5 and Table 6 (Lines 519 to 521) is based on comparison to contingency guidelines from various industry sources. It is my understanding that those guidelines must be based on the conventional practices where estimators heavily use addenda for bidding.

Thank you, the authors have added some additional information about the 95 data points to the extent that the rather strict confidentiality agreements with the data sources, who enabled this research, allow. The respective extended section now reads as follows:

The scope of this research specifically includes cost and impact of the design uncertainties within the bid documents for structural steel framing. The exemplary data that are selected for this research are public school projects from the Washington metropolitan area (consisting of Washington, DC, Northern Virginia, and Maryland), which contain substantial amounts of structural steel. Besides, they feature a uniform design and their data are readily accessible from the public owners of the respective school systems. Three of the nine school projects in the data were located in each state for an even coverage. The substantial amounts of plan drawing and specification pages that have been analyzed per project are listed in Table 2 of the companion paper (Duzkale and Lucko 2015). These school projects have similar structural design characteristics. Each project design had structural steel framing that consisted of steel beams and columns plus steel joists on load-bearing masonry walls. The design loads and the overall geometry of the structures were similar due to close geographical proximity of the projects and typical functional requirements for the intended users. The word ‘plan’ in this research study will mean all of the design drawings, which can be elevations and sectional, detail, and top views.

The unclear sentence was clarified to state that all addenda prior to the bid opening were of course included in the data that were analyzed in detail. Note also that this research per its title deals with bid preparation until the exact moment of bid opening, not with later change orders or contract addenda during the ongoing construction. It now reads as follows:

Corrections to bid documents in any addenda that may have been issued by designers after the bid opening date or during construction have been excluded; therefore future research should analyze addenda, contents of changes, and costs to better understand how project participants are dealing with uncertainties that were undetected or unresolved until it was ‘too late’. All changes to design that were included in the addenda and issued before the bid date were included in the data.

b. The study is mainly focused on uncertainty clarification and significance. So, the authors are
suggested to elaborate how the study results can actually help "reduce" uncertainties, as stated in Line 570.

Thank you, the authors have added more thoughts on how this research can be used by practitioners to achieve such reduction. The respective extended section now reads as follows:

This research is a key step towards improvement of the bid documents for increased accuracy of structural steel estimates by investigation of uncertainties in the bid documents. The primary goal of the research was to reduce uncertainties in bid preparation for structural steel. Finding, classifying, and measuring uncertainty has added vital knowledge to the construction industry for increasing the bid agents’ cognizance of the uncertainties from a steel estimator’s perspective. In practice, this research sensitizes to the issue with hard statistical data instead of empirical rules of thumb. Its quantitative approach can inform steel estimators within the geographic region of this study on how to attempt to remedy an uncertainty if clarifying information cannot be obtained, and how to best set a contingency if they incur one of the major types of uncertainties.

5) Consider providing project information about the 9 school projects, for readers information.

Thank you, the authors have added some additional information about the 9 school projects to the extent that the rather strict confidentiality agreements with the data sources, who enabled this research, allow. The respective extended section now reads as follows:

The scope of this research specifically includes cost and impact of the design uncertainties within the bid documents for structural steel framing. The exemplary data that are selected for this research are public school projects from the Washington metropolitan area (consisting of Washington, DC, Northern Virginia, and Maryland), which contain substantial amounts of structural steel. Besides, they feature a uniform design and their data are readily accessible from the public owners of the respective school systems. Three of the nine school projects in the data were located in each state for an even coverage. The substantial amounts of plan drawing and specification pages that have been analyzed per project are listed in Table 2 of the companion paper (Duzkale and Lucko 2015). These school projects have similar structural design characteristics. Each project design had structural steel framing that consisted of steel beams and columns plus steel joists on load-bearing masonry walls. The design loads and the overall geometry of the structures were similar due to close geographical proximity of the projects and typical functional requirements for the intended users. The word ‘plan’ in this research study will mean all of the design drawings, which can be elevations and sectional, detail, and top views.

Some minor comments are as follows:

6) Although the writing quality is overall OK. There are a number of sentences that could have been written better (e.g., Lines 81 to 82; Lines 109 to 110). Consider reviewing and revising them.

Thank you, the awkward punctuation of a question mark within a sentence has been remedied. The dense use of multiple nouns was softened in the latter sentence, which now reads as follows: More specifically, the subquestions are (1) what is the significance in terms of the absolute and relative cost impact of each major type of uncertainty; and (2) are contingencies that are often suggested and used of an order of magnitude that covers the actual bid document uncertainties and other risks?
**Compare in the order or magnitude and value of suggested contingency percentages from current practice with the results from this research.**

7) There are too many uses of italic.

Thank you for this comment, the authors have striven to be very clear in presenting this complex subject, but realize that the use of italics may need to be reduced, which has been done. The highlighting of the five uncertainties has been retained.

8) The future tense is mix-used with the past tense when it comes to explaining the research activities. It is my understanding that the authors meant to say that the activities explained in Section 4 have already been performed?

The authors have also checked Section 3, which is present perfect when speaking about the preceding companion paper and present when describing the summary figure in this paper. Section 4 is present tense to establish the hypothesis, and future tense for work that will be done.