# CASE STUDIES: EVALUATING BUILDING INFORMATION MODELING IMPACT ON UNITED STATES ARMY CORPS OF ENGINEERS CONSTRUCTION

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## ABSTRACT

Highlighted as test bed Districts for BIM implementation in the "U.S. Army Corps of Engineers (USACE) Building Information Modeling (BIM) Road Map," Seattle and Louisville accomplished in-house BIM designs in 2005, three years before any other of the 43 Districts across the United States transitioned to a BIM-centered approach in 2008. However, while perceived benefits of BIM used on these test bed jobs are driving Corps-wide changes on billions of dollars of construction, these BIM-based projects were never critically evaluated for their benefits in the construction phase, creating a need for further investigation. Therefore, this research addressed the need and assessed BIM impact on construction projects according to the U.S. Army Corps of Engineers (USACE) internal metrics, the Consolidated Command Guidance (CCGs) metrics for military construction. Information garnered in the survey phase prior to onsite research at the Districts was used to guide research methodology assessing BIM effects on construction projects in the USACE Seattle and Louisville Districts. This research documented both quantitative and qualitative evidence demonstrated in BIM-based projects in Seattle and Louisville compared to similar projects (by facility use category code) to determine a correlation between BIM-based design and construction.

## KEYWORDS

Building Information Modeling (BIM), Key Performance Indicator (KPI),
United States Army Corps of Engineers (USACE), construction, metrics

## 1. INTRODUCTION

Building Information Modeling (BIM) is an integral part of the design and construction process in the United States Army Corps of Engineers (USACE). This is primarily because of two events: 1) the promulgation of *MILCON Transformation* and its associated Centers of Standardization (COS) effort & 2) The publication of ERDC TR-06-10, or the Army's "BIM Road Map." Due in large part to two test bed BIM designs accomplished in-house in the summer of 2005 in the Seattle and Louisville Districts, BIM is now required for the 42 standard facility types described in the COS effort. However, as the authors of the BIM Road Map discuss within the document, their reasons for mandating a BIM approach are anecdotal and not based on metrics related to design or construction (USACE 2006).

The hypothesis for this research is that there is a positive correlation between a BIMbased approach and construction management productivity. Therefore, qualitative and quantitative data was collected to evaluate a BIM-based design's impact on construction. In "Phase I," surveys were administered to assess practitioners' perceptions about BIM's impact on construction in relation to researched Key Performance Indicators (KPIs) of documented value to the construction industry (Cox et al. 2003). In Phase II, embedded research was accomplished on-site in Seattle and Louisville to garner qualitative and quantitative data regarding BIM effects on construction through the USACE's internal metrics, the Consolidated Command Guidance (CCG) program.

## 2. BACKGROUND

**Why BIM?** In 2004, the National Institute of Standards and Technology (NIST) published a report stating that poor interoperability and data management cost the construction industry approximately $15.8 billion a year, or approximately 3-4% of the total industry (Gallaher et al. 2004). Since this report, many have labeled Building Information Modeling (BIM), an emerging technological information management process and product, as the answer to this problem. From the National BIM Standard (NBIMS) published in December 2007, a BIM (i.e. a single Building Information Model) is defined as "a digital representation of physical and functional characteristics of a facility." Furthermore, a BIM represents "a shared knowledge resource, or process for sharing information about a facility, forming a reliable basis for decisions during a facility's life-cycle from inception onward." In the words of former NBIMS Executive Committee Leader and current Executive Director of the International Alliance for Interoperability (IAI) buildingSmart Initiative, Dana K. "Deke" Smith, FAIA., "A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder" (NBIMS 2007). In fact, in NBIMS Chapter 4.1 "Minimum BIM," where it discusses what constitutes a "minimum BIM," the basis for writing this section was the U.S. Army's BIM Road Map – showing again the importance of the Army BIM Road Map.

**Construction Productivity** In a 2007 follow-up research effort to the NIST report from 2004, NIST's Building and Fire Research Laboratory (BFRL) researcher, Robert Chapman, stated that, "Construction industry stakeholders need compelling metrics, tools, and data to support major investments in productivity enhancing technologies. The development of metrics, tools, and data is complicated because each measurement level (i.e., task, project, and industry) has many different analysis requirements."

While there are large organizations engaged in benchmarking and creating metrics like those discussed by Chapman, organizations like the Construction Industry Institute (CII) have created metrics that are primarily **task-based** (Thomas 2002). At the other end of the spectrum, with large organizations like the Bureau of Labor Statistics (BLS) tracking metrics that are primarily **industry-based**, there are few, if any, metrics tracked on the project management level from the owner's perspective. This research focused on two project-based sets of metrics from the perspectives of a contractor and from an owner.

**Metrics for Construction Productivity—The USACE Consolidated Command Guidance (CCG) Program** As it is well known in the construction industry and corroborated in Adrian's book, *Construction Productivity: Measurement and Improvement*, "the success or failure of every construction project can be measured in terms of four variables: cost, time, quality, and safety" (Adrian 1995). Similarly, these are aligned with the primary metrics that USACE uses to evaluate its own competency is the CCG program. The USACE CCGs attempt to compare past or current performance to an expected norm. There are a myriad of CCG metrics used to evaluate every phase of USACE work from design to sustainability, but there are five specific CCGs primarily used to evaluate construction productivity. These five CCGs are found in the USACE construction administrator's automated management application, called the Resident Management System (RMS) are metrics MP-6 through MP-10. From the RMS, geographically disparate construction managers or contract administrators can add data or query USACE databases for real-time status updates on any of the active or completed projects in the USACE. Status is reported back in the following, simplified fashion:

- Green: CCG metric has met or is meet the goal
- Amber: CCG metric has not met the goal by a slight margin
- Red: CCG metric has not been met and is not close to being met

Below are a list of each specific metric and their accompanying goals, from the Honolulu District's guidance (Won 2007):

- MP6: Construction Project Cost Growth
    i. "Is the project's current cost of construction within 5% of the awarded contract amount?"
- MP7: Construction Project Time Growth
    i. "Is the project's scheduled construction completion within 10% of the original contract duration?
- MP8: Project Beneficial Occupancy Date Time Growth
    i. "Is the project's scheduled BOD within 10% of the original BOD?"

- MP9: Project Construction Timeline
    - i. "Is the project's overall delivery schedule within the timeline guidelines based on the PA amount?"
- MP10: Project Financial Closeout
    - i. "Is the project's scheduled fiscal closeout within 12/15 months of BOD?"

When evaluating construction projects individually, each project can only "meet" or "not meet" the goal. However, for the regional Districts, or their higher sub-regional headquarters called "Divisions" (which consist of multiple, subordinate "Districts"), the metric is "expressed as a percentage of the sum total of number of on-going projects in program years (PYs) 02-06 meeting the Cost Growth goal" (Strock 2006). Then the average sum total when dealing with an entire District or Division is broken out into the green, amber, red ratings. For each metric, the performance level and the windows of opportunity for achieving a "green" rating vary accordingly. For example, for MP-6 "Construction Project Cost Growth," the goal is to "manage on-going MILCON Project construction through contract completion with no more than 5% total project cost growth" (Strock 2006). Therefore, for a single project to achieve a green rating would require that the project's cost could grow no more than 5% for the "sum of all construction cost growth from Military Construction (MILCON) funded contracts executing a project" (Strock 2006). If it did not meet this goal, the project would simply be classified as "did not meet goal." However, collectively, an amber rating would be achieved for 85-95% of the projects meeting the cost growth goal and a red rating would be applied for below 85% of the collective projects meeting the goal. Therefore, in the figure showing the CCG report from RMS querying all on-going projects for all Program Years, metrics MP-6 and MP-7 for the USACE are Amber with 89% for MP-6 and Red for MP-7 with a 68% rating.

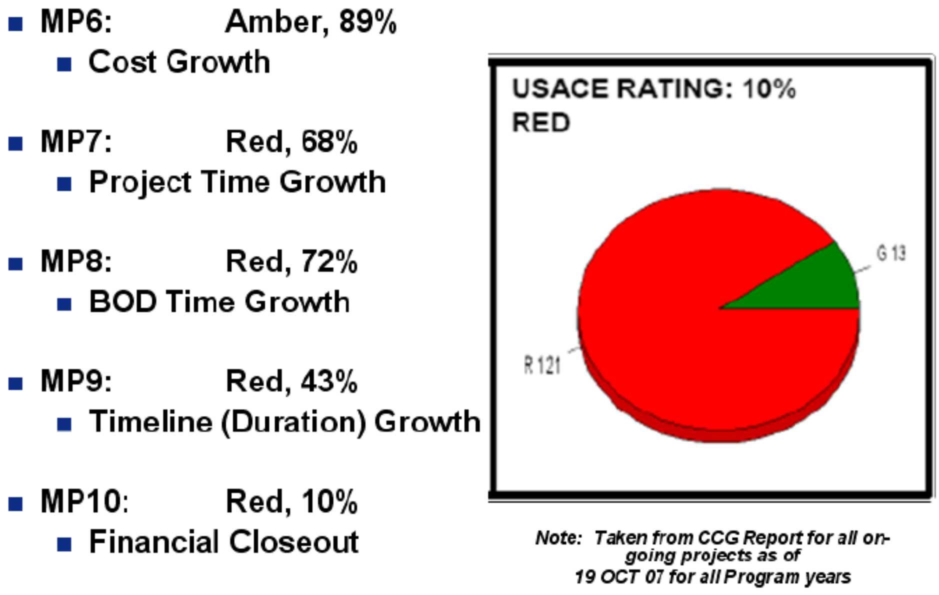


Figure 1. USACE CCG Report, 19 OCT 07, showing range of 10%-89% meeting their metrics

As shown in Figure1, the Army is not meeting their goals. In fact, as of the date that report was queried on October 19, 2007, the USACE was red in four of the five metrics tracked in RMS, and, as shown in the figure above, only achieved an amber rating in the last remaining non-red metric. Clearly a change is needed and the army hopes to change this current level of performance.

**MILCON TRANSFORMATION**

The USACE's FY 08 Military Construction budget was $18.3 Billion. These projects included worldwide traditional MILCON projects such as Ranges, Barracks, Housing, and work on Host Nation Construction Management and Oversight in places like Germany, Japan and Korea (Temple 2007). With a construction budget this large, the USACE is one of the largest construction owners in the world. However, as seen in Figure 1, their current program execution needs improvement.

The strategic level program for ameliorating the current inefficiencies and meeting future challenges is called "MILCON Transformation." It is MILCON Transformation that drives the recent initiatives towards change in the Army Corps of Engineers. From former USACE HQ Commander and Chief of Engineers, Lieutenant General (LTG) Carl A. Strock, MILCON Transformation can be attributed to Deputy Assistant Secretary of the Army (Installations & Housing) Joseph W. Whitaker. In November 2004, Secretary Whitaker directed the Corps of Engineers to develop a strategy and implementation plan in support of Army Transformation to provide the Army the ability to establish, reuse/re- purpose facilities with minimum lead-time, leverage private industry standards and practices, and reduce acquisition/lifecycle costs. His direction recognized the urgent need for a massive, multi-year construction program to provide new facilities. The initiative developed in response to Mr. Whitaker's task assignment is now known as MILCON Transformation and is an important element of the Army's Business Transformation. This strategy was created in a partnership between the Corps of Engineers, the Office of the Assistant Chief of Staff for Installation Management, the Installation Management Agency, private industry and Mr. Whitaker's office. Key elements include standardization in acquisition processes, standardization of design of facilities and expanded opportunities for use of alternative construction methods such as manufactured building solutions (Strock 2007).

With the sheer size and massive budget for the work that the USACE oversees, MILCON Transformation is poised to have far reaching implications. MILCON Transformation includes a "disciplined emphasis on standardized facilities" and is designed to provide Soldiers with quality, sustainable facilities less expensively, in less time and on-time to allow the Army to meet its transformational schedules. Specifically, the USACE plans on 15% less cost on projects and 30% quicker time tables. With MILCON Transformation as the driver, the USACE has moved towards focusing on BIM as an answer. This comes from their formally promulgated mission and vision regarding BIM, in the Army BIM Road Map.

**The Army BIM Road Map** ERDC TR-06-10, "Building Information Modeling (BIM): *A Road Map for Implementation To Support MILCON Transformation and Civil Works Projects within the U.S. Army Corps of Engineers*" is simply known as the "USACE BIM Road Map." The BIM Road Map is a 96-page guide and requirements listing for successful BIM implementation in the Army Corps of Engineers. The USACE BIM Road Map is a product jointly executed by the CADD/GIS Technology Center, Construction Engineering Research Laboratory (CERL), and Engineering Research and Development Center (ERDC). While the BIM Road Map addresses many areas of possible contribution, the primary impetus for pursuing BIM, according to the authors, is to "drive down costs and delivery time" (2006). According to Seattle District CAD/BIM Manager, Van Woods who managed one of the real world BIM projects highlighted in the document, "driving down costs and delivery time" specifically meant that the USACE wanted to achieve economies of scale for repeatedly designing the same types of buildings, as well as reduce the average 18-month time from award to ground-breaking that the Corps was experiencing. As seen in the title, the BIM Road Map was an attempt to support "MILCON Transformation" within the USACE. The Army BIM road Map can be seen as the technological vehicle for making the logistic requirements of the COS initiative a reality (Woods and Solis 2007).

**The Centers of Standardization Initiative** Also support of MILCON Transformation, the Army published memorandum from now Major General (MG) Merdith W.B. Temple, the Director of Military Programs, on March 06, 2006 regarding "Realignment/Establishment of Centers of Standardization (COS), FY-06" (Temple 2006). In the COS memorandum, General Temple broke with the traditionally regionalized Division and District areas of expertise and established centers of standardization that would serve as design authorities for 42 different types of facilities in different Districts across the CONUS and even in Hawaii. The traditional model was for the Corps to focus on all MILCON and Civil Works projects within their region and contract out 75% of the work to contractors while retaining 25% of the design work in house. Now, under the joint COS and USACE BIM Road Map guidance, the 42 facility types will be designed via a BIM approach and altered to fit site conditions at each District. More importantly, each COS will establish regional Indefinite Quantity (IDIQ) contracts that will administer "services associated with assigned facility types." This means that firms who "win" the original design solicitations for the BIMs for these 42 jobs will in essence have a contractual lock on the design services EVERY time that building is modified and built in any USACE District in the United States, and that each District that serves as a COS will have an IDIQ to provide millions, and possibly billions, of dollars in services to construct these facilities across the United States. Quite simply, the impact is staggering.

However, the USACE BIM Road Map is a step towards alleviating those fears by clearly spelling out lessons learned and best practices for Districts to follow when formulating their in-house or contract-led BIM efforts. Based on design work accomplished in the Seattle and Louisville Districts, the USACE BIM Road Map discusses the strength of BIM, as well as how best to implement it through a discussion of requirements, and both short term and long term strategic goals. Possibly the most beneficial to the technical or tactical level BIM implementer are the Appendices which discuss the goals in depth, the specific implementation plan, "dataset evolution instructions" (file structure library recommendation), organizational recommendations, contract language, oversight and implementation guidance for working A-Es, personnel position descriptions, and other related roles and responsibilities. All in all the BIM Road Map would be beneficial to any BIM neophyte and is both concise and thorough in a way that most other documents of its kind have not achieved.

The USACE has created indicators that are both ambitious and realistic. By phasing their strategy, they have avoided the trap of "over promising" benefits that the technology cannot deliver. This also allows time for the culture within the USACE to change and to gradually phase in BIM in the best, most practical way in a traditional spiral fashion, indicative of other successful IT implementation initiatives. Appendix A outlines six "goals" that build on the four phases and seven milestones discussed above. Goal 1 reads, "Establish Metrics To Use for Measuring Process Improvement," however no such metrics have been created since the document's publication at the end of 2006 (USACE 2006).. This is the impetus for this research.

## 3. METHODOLOGY

### USACE DISTRICT CASE STUDY INTERVIEWS

Research was conducted on-site in the Seattle and Louisville Districts in the summer of 2007. The following information summarizes the information gleaned in the interviews:

**Seattle District (NWS)** The pilot BIM project designed and managed by USACE-Seattle District was an enlisted unaccompanied personnel housing (UPH) barracks project at Fort Lewis, Wash. The project consisted of a total of seven barracks buildings, including two campus style barracks complexes designed to house 300 and 239 people, respectively.

Van Woods, CAD/BIM Manager, noted some missed opportunities when he lamented that Seattle's estimators used neither the quantity take-off nor estimate from the model the designers provided. Instead, the estimators "trusted their experience over the BIM software." When the traditional process yielded a significantly higher figure than the initial government estimate, the estimators returned to the designers for help. The explanation was that the estimators had included one kitchen arrangement (e.g. refrigerator, stove, sink, etc.) for every person in the barracks, when in reality there was only supposed to be one kitchen set for every two people. This problem could have been easily avoided had the estimating team used the virtual building model, which clearly indicated the correct quantities and provided an accurate estimate.

When talking to Mr. Bruce Hale, the lead architect, the primary theme was that, "**BIM provides a lot of promise, but that the cultural and training hurdles necessary for overcoming transition to the new process were more difficult than predicted**." Due in large part to the lessons learned in Seattle and Louisville regarding training, the USACE and their BIM software partnered to establish a pedagogical approach to learning their BIM software that included 3-5 weeks of training, with a 1-week introduction to the software followed by 2-4 weeks of intense training where designers work together to apply newfound BIM knowledge to an Army Center of Standardization (COS) standard facility type. Therefore, all eight geographically disparate COSs were trained by the end of FY07 with sound training plans that resulted in tangible benefits and real design drawings. A final challenge that Seattle uncovered was the lack of metric “assemblies” (or sample content) available in 2005. The design team was forced to convert or modify every assembly from imperial units to metric one-at-a-time, eliminating a benefit of BIM that is more prevalent today. Conversely, there are widely available project assembly data that can be used “off the shelf” in any project to rapidly advance the design phase.

Lastly, after interviewing Mr. John Herem, the Chief of Contract Administration for
Seattle District, he said that aesthetically, the BIM design on this project was embraced by the user. But from a contractual standpoint, it was “as good as any other design” when it came to the quality of the construction documents. Ultimately, he wished that the contractor would’ve had the knowledge and training to work with the **virtual model** rather than just the construction drawings; but since this was not the case, the project suffered significant construction management issues caused by the contractor that could have been avoided. In particular, there were structural and mechanical issues and scheduling/phasing difficulties that could have been avoided if the contractor was more active in using the model to visualize, and in turn, manage a successful project. In the big picture, operating in a BIM environment leverages information to transform the building supply chain through open and interoperable information exchange, while contracts only stipulate legal minimums. In other words, “when you do things the way you always did them, you get what you always got.” Seattle found that operating in a BIM environment gave them an edge, but because of lack of buy-in, the contractor did not.

**Louisville District (LRL)** The pilot BIM project completed by USACE-Louisville District was a U.S. Army Reserve Center with an organizational maintenance shop built on land leased from North Carolina State University in Raleigh, N.C. The primary benefits noted in the Louisville District’s BIM project can best be summarized as “products, people and processes.”

**PRODUCTS.** The Louisville District’s roots in 3D, object-oriented design began in the late 1980s with its proprietary interface, the Modular Design System (MDS). This tool was used to design repetitive layouts and arrangements for the Support Team, Army Reserve (STAR) in Louisville on all Army Reserve projects. Whereas the Seattle District started with no library of data, the Louisville District’s transition to BIM began with importing and updating the knowledge base preserved in the MDS databases. This enabled the project team to overcome design challenges like those encountered by the Seattle District during its pilot project.

**PEOPLE.** The Louisville District also took great care in forming the team that would manage its first BIM-based project, hand-picking team members who were open to change and who possessed good communication skills. After initial attempts by individual design team members to achieve progress on their own proved ineffective in early 2005, the Louisville District transitioned to an approach it called the BIM Process Initiation Team (PIT), whereby all members of the design team received training that incorporated the project requiring design.

During the first week, members worked on real engineering and architectural requirements for the project. In the subsequent weeks, members were coached by the trainer and BIM manager to complete the design. Because of this accelerated, integrated design effort, the Raleigh project was designed and ready for solicitation approximately eight months before the STAR-imposed deadline.

**PROCESSES.** The Louisville District’s BIM team achieved success by standardizing their BIM-PIT workflow and data management. Much of its work serves as the basis for the *USACE BIM Roadmap* section discussing the BIM data workflow and management processes that will be used USACE-wide on approximately $24 billion of military construction annually.

## 4. CCG COMPARISON AND DISCUSSION

In order to collect the data on BIM-based projects versus non-BIM-based projects, the USACE Resident Management System (RMS) database administrators were contacted. They added a toggle box in the *Contract Description* area that allowed users to note whether or not a project was considered "Building Information Model (BIM) Compliant." (Figure 2) In this way, known and future BIM projects could be easily differentiated for research purposes.

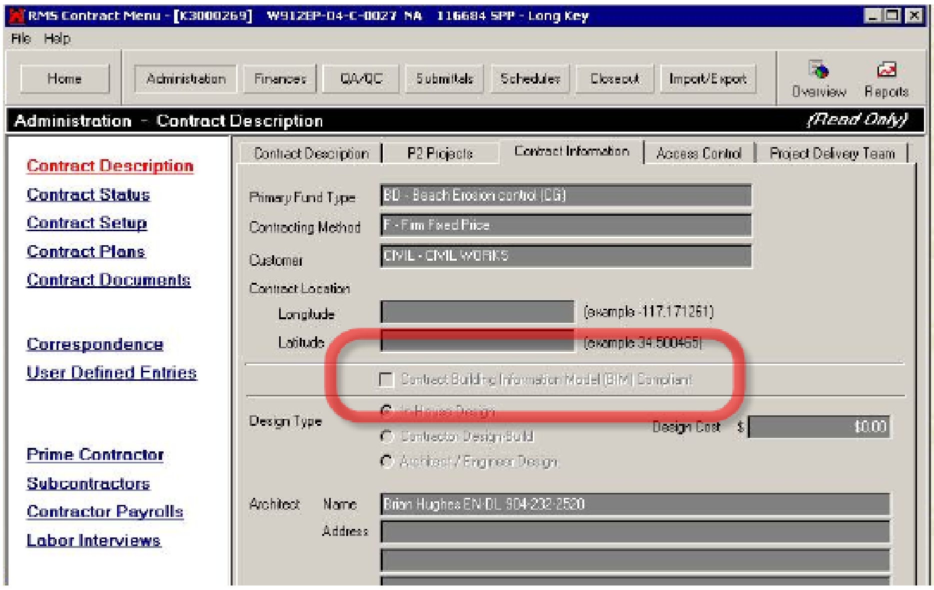


Figure 2. New "BIM Compliant" toggle box in Resident Management System (RMS) construction management database interface (Note non-compliance on this project)

Next, a data extraction was accomplished using the Consolidated RMS (C-RMS) database. In this query, projects with the barracks facility category code (72111) or Army/Armed Forces Reserve Center category code (17140/17141) were compared to the test bed BIM projects in Seattle and Louisville, respectively. Therefore, all completed projects of the aforementioned facility category codes and meeting the requirements necessary to appear in a CCG report were generated. This yielded 27 individual projects completed from 2002-2007 in various locations around the United States. Using the central limit theorem, the data was summarized and evaluated for 90% and 95% confidence intervals to describe the field of 27 projects.

Next, the two pilot BIM projects' metrics from Seattle and Louisville were compared to the metrics from all the similar, completed projects from the past. Using the data from these two projects, their information was compared to the confidence interval data from the past completed projects. Results were accumulated individually by applying the same procedure to past projects CCG data and creating statistical norms through the Central Limit Theorem (CLT) approach. This included calculating the mean, standard deviation, standard error and then 90% and 95% confidence intervals for the data based off the 90% and 95% t values. Upon completion, the BIM-based projects were compared through simple, automated "IF" statements in the spreadsheet that labeled the result with one of three possible choices: "OUTSIDE (red or blue)" and "INSIDE (green)." If the result was INSIDE, then the BIM-based value was within the CI for the given metric. If the label was OUTSIDE, then the BIM-based project's performance was either highly favorable or highly unfavorable and outside the CI.

In summary, the two pilot projects scores were very different. While the Louisville project never scored unfavorably outside the confidence intervals, it scored very favorably in cost, modification amount, time growth, and duration. The Seattle BIM project scored very unfavorably in five of eight possible areas dealing with time growth and overall duration, but was inside the CI for cost and typical duration of actually completed projects. A summary of the percentage of each label can be seen in Figure 3.

| | CI | OUTSIDE | INSIDE | OUTSIDE |
|---|---|---|---|---|
| Louisville | 95% | 0.00% | 38.89% | 61.11% |
| | 90% | 0.00% | 33.33% | 66.67% |
| Seattle | 95% | 33.33% | 55.56% | 11.11% |
| | 90% | 33.33% | 55.56% | 11.11% |

Figure 3. Summary Table of BIM-based projects results when compared to 90% and 95% Confidence Intervals (CI) of the control population of completed construction projects

### DISCUSSION – LOUISVILLE PROJECT

When comparing the Louisville BIM-based project to the control population, it appeared to score very well. However, this could have been due to a relatively small project with an exaggerated timeline. This possibility became apparent when noticing that it met every CCG, sometimes even favorably outside the CCG CI, but actually did not meet the MP-9 metric for completing the project inside the administrative window for projects of its typical cost. In this way, the Louisville project no longer appears to have scored as well as some of the statistics would indicate.

### DISCUSSION – SEATTLE BIM PROJECT

When comparing the Seattle BIM-based project to the control population, the words of the Contract Manager, John Herem, come to mind, “Seattle found that operating in a BIM environment gave them an edge, but because of lack of buy-in, the contractor did not.” The technological benefit of the BIM-based was never realized by the contractor, who faced many problems once on site including interferences as well as weather and mold delays due to their administration of the project and approach with the unusual material type of Heavy (Type V) Timber construction in the Pacific Northwest. Conversely, had they taken advantage of the virtual building model, it is likely that some of their problems could have been avoided.

## 5. CONCLUSIONS

It was noted that overall the Louisville BIM-based project had statistically significant (when compared to the control population in this research) less modifications on their project than the typical barracks or reserve center facility projects. This information substantiates data collected in earlier surveys where practitioners responded that they thought “quality” was the biggest key performance indicator of the construction phase aided by BIM in the design phase. However, the Seattle-based BIM project, which demonstrated the stochastic nature of typical construction projects showed little impact from its technologically superior BIM design, due to common construction management problems like time growth due to HVAC interferences, weather, and mold.

However, the hypothesis for this research was that there is a positive correlation between a BIM-based approach and construction management productivity. Through qualitative means (interviews) and quantitative means, (statistical analysis) the BIM-based projects did, in fact, demonstrate varying levels of positive impact. However, with the limited sample size and scope of the control population, this data should only be used to establish correlation and not causation. As indicated by the Seattle project, more complex models would be required to account for the myriad of variables that exist in the design and construction facility lifecycle. In addition, much more data would have to be collected in order to make any claims about BIM-based designs causing construction productivity gains.

However, the business case and argument for the USACE to adopt this approach is compelling. Currently, their internal metrics, the Consolidated Command Guidance (CCG) program has no way of determining if their innovation will yield any significant results on a portfolio-wide level in line with their goals. In the Corps' move to breakdown the geographic boundaries and focus on optimizing construction by facility type, they need an approach that establishes statistically sound confidence intervals to allow them to know what to expect, reward/emulate those projects that surpass their expectations, and evaluate/document those projects that fall short of their expectations.

It is recommended that the USACE adopt a procedure to allow for the use of their meticulously collected data for documenting benchmarks whereby similar projects of type, cost, and duration are compared. Administratively-driven metrics are of little value and fail to reward superior performance and only document the existence of inferior performance.

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