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WHITE PAPER

# Color Construction Documents: A Simple Way to Reduce Costs



THE DIGITAL IMAGING AUTHORITY

# Color Construction Documents: A Simple Way to Reduce Costs

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### ABOUT THIS WHITE PAPER

This Lyra Research white paper was commissioned by Océ North America and is based on research and analysis Lyra developed between January and April 2010. All analysis and opinions contained herein are copyrighted material of Lyra Research, except where otherwise noted.

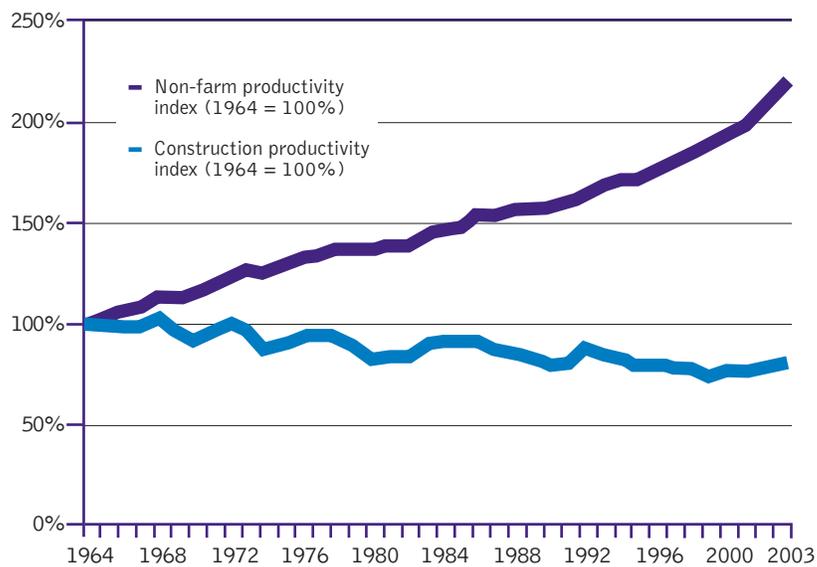
“It isn’t that they can’t see the solution, it’s that they can’t see the problem.” **G.K. Chesterton**

**EXECUTIVE SUMMARY**

Since the 1960s, U.S. businesses have achieved substantial gains in annual productivity through a variety of improved business processes, computing technologies, and related applications. These productivity gains can be measured in most major industries, including manufacturing, financial services, and transportation, to name a few.

During the same period, the productivity growth rate for the construction and building industry has averaged -0.59 percent, while all other industries (excluding construction) combined have an average productivity growth rate of 1.77 percent (see Figure 1) [1]. This relative decline has occurred even though the construction industry and other U.S. industries have access to many of the same technologies. To determine a source for this problem, industry experts point to many anecdotal and generally plausible causes, including system interoperability, largely for computer-aided design (CAD) tools, as well as project collaboration.

**Figure 1 | Construction and Non-Farm Labor Productivity Index, 1964 – 2003\***

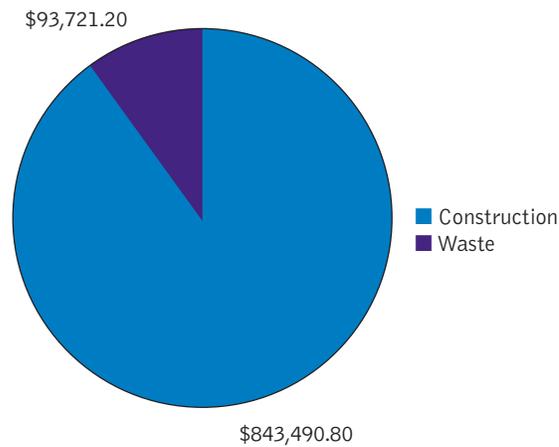


Source: Paul Teicholz, 2004

\*Constant cost of contracts/work hours of hourly workers

General industry estimates claim that between 10 and 30 percent of all building project costs can be attributed to wasted activities, such as schedule overruns due to inaccurate coordination scheduling, wasted labor and management time, wasted materials, and unnecessary litigation (*see Figure 2*) [2]. Based on U.S Department of Commerce building estimates for 2009, a 10 percent waste factor is equal to approximately \$94 billion [3]. While this figure does not specifically indicate what is causing productivity rates in the construction industry to decline, it does reveal a significant opportunity for waste reduction and productivity improvement that could help to address the problem.

**Figure 2 | 2009 Total U.S. Construction, Estimated Waste in Millions**



Source: U.S. Department of Commerce, 2010, and Barry LePatner, 2008

### Objective

To find an effective solution to this problem, we need to clearly understand its cause and assign realistic values to it. Once qualified and reasonably quantified, we can measure the investment that is required to solve it. This paper's focus is on inadequate collaboration based on the insufficient quality of construction documentation used for the dominant project model of construction, the design-bid-build process. Our objective is to measure the anticipated cost savings that can be gained by leveraging the use of color construction documents in this project model. The product of this research is a flexible ROI model for measuring these costs and the return to be gained from the use of color construction documents.

### Result

The metrics developed for this paper have been compiled into an ROI model to provide a means for project executives and other construction business leaders to apply their historical knowledge of past and anticipated project costs and potential savings against the added cost of printing and distributing detailed color designs and project documentation.

Each incremental dollar invested in color printing can yield \$4 in savings for a given project.

### KEY FINDINGS

#### Collaboration Depends on Documentation Detail, Depth, and Color

Construction workflows that leverage color design and construction documentation and printing provide an important means for reducing costs for traditional design-bid-build projects. Relative to the cost of color printing, the improvements in collaboration gained through reduced estimation contingencies, requests for information and change orders can readily exceed a 4:1 ratio, in which each incremental dollar invested in color printing can yield \$4 in savings for a given project. These savings are derived through the use of higher-quality color construction documentation during the estimation, bidding, and construction phases of building where collaboration extends across multiple downstream stakeholders, such as specialty subcontractors, fabricators, and suppliers.

Additional findings include:

- On a per project basis, the value of color CAD printing is high, while the cost is negligible relative to the return in savings from comprehensive color workflows that Building Information Modeling (BIM) and/or color CAD designs enable.
- Despite the potential return and minimal investment requirements, color CAD documentation techniques are generally underutilized in building projects.
- Color CAD systems are widely in place today, and construction documentation and designs created in CAD are created natively in color, which can readily increase the quality and detail in conceptual designs for estimating, bidding, and preconstruction activities. Compared with the upfront costs required to implement BIM, including software, computing hardware, staffing, and training, color CAD documentation workflows can be implemented more quickly and with less overhead.

**PROBLEM SUMMARY**

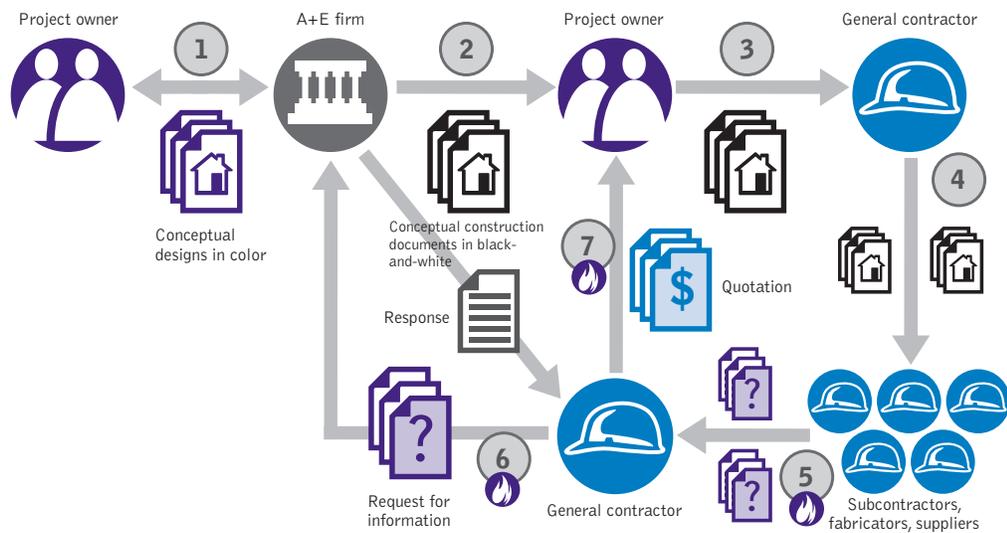
**Risk Mitigation and Collaboration**

Construction is a complex process that often involves multiple stakeholders collaborating and coordinating a complex series of tasks in unpredictable conditions, under rigid deadlines. The majority of projects are unique, and strict limitations regarding how each stakeholder participates in the process make the risks involved difficult to foresee. Effective collaboration requires effective communication. In construction, communication begins with building designs, and the quality of collaboration deteriorates as the level of detail in communicating project requirements decreases from one stakeholder to the next, creating unnecessary cost and waste. Advanced technologies, including BIM and color CAD printing, provide platforms for effective project collaboration among stakeholders, yielding significant cost reduction opportunities in the form of cost control, greater productivity and profit. The early successes found in projects that leverage BIM and design-build processes reveal specific areas in which previously inadequate collaboration is a critical source of project waste and lost productivity.

**Qualifying the Problem**

Collaboration breaks down between stakeholders for a variety of reasons, but the leading cause appears to be inadequate design and construction documentation provided by architecture and engineering (AE) firms to general contractors for estimating and bidding on projects using the design-bid-build method (see Figure 3). Projects managed through BIM and three-dimensional models improve collaboration largely because these methods require an increased level of detail to create useable design and construction documentation [1] [2].

**Figure 3 | Design, Estimation, and Bidding**



Source: Lyra Research, Inc., Color Construction Documents: A Simple Way to Reduce Costs, April 2010

AE firms draft building designs to meet owners’ conceptual project requirements, but these designs overlook the level of detail that general contractors require to determine the constructability of a project (see stages 1 through 2 in Figure 3). General contractors typically enter the building project well after the project owner has approved the building designs (see stages 3 through 4 in Figure 3). As a net

Conceptual designs provide, at the most, approximately one-half of the level of detail required to actually determine whether it is feasible to build a structure.

result, general contractors, subcontractors, and suppliers generate a larger than necessary number of RFIs to better understand the designs and project requirements (see stages 5 through 6 in Figure 3). To avoid excess risk, both subcontractors and general contractors tend to build in higher-than-necessary cost contingencies based on their perception of the project's complexity (see stage 7 in Figure 3). This process generates the first level of waste, primarily from excessive contingency costs that are required to mitigate the risk of insufficient design details.

Discussions between business leaders and industry participants indicate that conceptual designs provide, at the most, approximately one-half of the level of detail required to actually determine whether it is feasible to build a structure (see Figure 4).

**Figure 4 | Design Document Comparison**



Source: Lyra Research, Inc., Color Construction Documents: A Simple Way to Reduce Costs, April 2010

The design information, including sketches, cut sheets, and shop drawings, typically lack critical information, including examples such as the following:

- 2D images, which are typically distributed as black-and-white PDFs; and
- 3D images, which are limited in availability to general contractors and partners and may lack many structural and system specifications and details required for accurate quantity takeoff, job costing, and coordination scheduling.

This ambiguity adversely impacts construction processes and costs in the following ways:

- **Estimation contingency:** Increases the cost of a project by a factor derived through less accurate job costing from both the general contractor and subcontractor.
- **Change orders:** Reduces the ability to control unanticipated project costs due to a lack of clarity regarding site requirements and coordination scheduling, for example.
- **Management costs:** Increases the amount of time required to manage the change-order process.
- **Request for information (RFI):** Leads to an increased number of RFIs, which drives up operating costs for all stakeholders responsible for managing this process.

**SOLUTION SUMMARY**

Technologies that can effectively solve the problems discussed above exist, but they are underutilized in the construction industry. How can AE firms be motivated to produce and provide better documentation for design-bid-build projects thus reducing costs for general contractors and owners?

One potential solution to this problem is to develop a functional method for measuring the waste that poor documentation creates and the potential savings that higher-quality documentation and color CAD workflows can provide.

**Quantifying the Business Problem**

Reviewing secondary sources, as well as information gathered through several interviews conducted with key decision makers (primarily general contractors), we have developed a simple model for quantifying the waste incurred from unnecessary estimation cost contingencies, change orders, and RFIs. These impacts are isolated to general contractors but span the design and construction phases of a given building project. We have separated these waste cost factors into two broader categories:

- Operating costs – include specific square-foot values for managing RFIs and change orders.
- Project costs – include the net value of estimation cost contingencies and the net value of change orders.

*Operating Costs — RFI and Change Order Management*

Operating costs include costs that impact the bottom line of the stakeholder—in this case, the general contractor. For the purposes of this paper, we have narrowed the analysis to focus on the two operating costs that can be most easily addressed during construction: RFI management and change-order management.

In 2004, the National Institute for Standards and Technology (NIST) published a research report titled “Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry.” In this study, the NIST developed a cost model for a number of business processes that impact building projects and generate waste. For the purposes of this white paper, we refer to this study to determine general contractors’ RFI cost metrics during the design and construction phase of building.

According to the NIST study, general contractors waste approximately \$0.12 per square foot and \$0.16 per square foot during the design and construction phases of building, respectively, with RFI management (see Figure 5) [4]. For general contractors the “design phase” essentially involves the processes of estimating and bidding.

In order to measure the waste associated with change-order management, we extrapolated a separate cost from the RFI management metric during the construction phase, using a 2:1 ratio, or \$0.32 per square foot for change-order management (see Figure 5). (For more details regarding these figures, see the NIST Values section in the Appendix at the end of this document).

**Figure 5 | NIST Waste Factors**

	Waste per square foot of construction
RFI management (design phase)	\$0.12
RFI management (construction phase)	\$0.16
Change order management (construction phase)	\$0.32
<b>Total</b>	<b>\$0.60</b>

Source: Lyra Research, Inc., Color Construction Documents: A Simple Way to Reduce Costs, April 2010

*Project Costs – Estimation Cost Contingencies and Change Orders*

The second waste category includes project costs, which refer to the hard materials and supplies and labor costs that are required to meet the specifications for cost estimation or unexpected change orders. Based on interviews with construction executives, cost estimation contingencies vary based on the project complexity and the clarity of the documentation provided in a bid request. For moderately complex capital building projects, contingencies of 10 to 20 percent are considered common without the use of BIM or color 2D construction documents. Secondary research reveals that, industry-wide, between 5 percent and 7.5 percent of a given project budget will account for change orders [5][6]. Anecdotally, in discussions with business leaders, this percentage can be 30 percent or higher, depending on the complexity of a project.

We assume that a percentage of those change orders can be eliminated through the use of more effective construction documentation and color workflows, while the remaining change orders are derived from owner-requested changes and other factors that would not be caused by a lack of detail, errors, or omissions in project-design documents. We have consolidated these factors into two categories for estimation cost contingencies and change orders.

**Modeling the Savings Opportunity**

The following four-step ROI model represents a straightforward approach to measuring a realistic return or savings through the use of more effective construction documentation for a given project (see Figure 6). The ROI model requires a knowledgeable construction executive to enter the following series of variables for a given project. Based on those metrics, the model will calculate the estimated return on investment.

**Figure 6 | Step 1 – Estimating Waste in Project Costs**

	Example	Instruction summary
Project value	\$22,000,000	Input the total estimated project budget or bid price. For this example, the project includes a \$22 million mixed-use commercial/residential building.
Total square feet	150,000	Input the total estimated size of construction.
Project duration (months)	18	Input the total estimated duration for the project in months.
Estimation cost contingency	15%	Input an estimated cost contingency percentage for the overall project budget based on its general complexity. Based on the general contractors surveyed for this study, we understand that the typical project bid would include incremental cost contingencies equal to between 15 percent and 20 percent of the budget for projects that rely on traditional black-and-white construction documentation. To be conservative, for this example we used a cost contingency of 15 percent.
Change order contingency	2%	Input an estimated percentage of the project budget that will most likely be recognized through change orders. General industry averages range from 5 percent to 7.5 percent, but can be much higher. For this example, we used a 2 percent change order contingency, assuming that the estimation cost contingency will provide enough flexibility for moderate cost increases during the project and during reconciliation of other specification details and requirements during construction.
Change order reduction factor	50%	Input an estimated percentage of all anticipated change orders that will most likely not result from errors and omissions. This percentage allows the model to discount change orders that can not be prevented through improved construction documentation, or that originate as owner requested changes or enhancements. For this example, based on historical knowledge for this type of project, we estimate that 50 percent of the value of all change order requests will be initiated by the project owner.
RFI management (design phase)	\$0.12	Keep the NIST waste factor, or input a new value based on industry knowledge and experience. This metric will determine the estimated waste generated from the RFI management process during the design, estimation, and bidding phase of building.
RFI management (construction phase)	\$0.16	Keep the NIST waste factor, or input a new value based on industry knowledge and experience. This metric will determine the estimated waste generated from the RFI management process during the construction phase of building.
Change order management (construction phase)	\$0.32	Keep the NIST-derived waste factor, or input a new value based on industry knowledge and experience. This will determine the waste generated from the change order management process during the construction phase of building.

Source: Lyra Research, Inc., Color Construction Documents: A Simple Way to Reduce Costs, April 2010

Based on the example figures entered in Figure 6, the ROI model yields the addressable waste for this sample construction project (see Figure 7).

**Figure 7 | The Calculated Addressable Building Project Waste**

Waste category	Total addressable project waste
Operating costs – RFI and change order management (150,000 square feet x \$0.60)	\$90,000
Project costs – estimation cost contingency (\$22 million x 15 percent)	\$3,300,000
Project costs – change orders (\$22 million x 2 percent x 50 percent)	\$220,000
<b>Total addressable project waste</b>	<b>\$3,610,000</b>

Source: Lyra Research, Inc., Color Construction Documents: A Simple Way to Reduce Costs, April 2010

For the next section of the ROI model, we input waste reduction factors for the addressable operating costs, starting with a 10 percent reduction in waste for RFI and change-order management. For this example, we assume the project will incorporate 2D color CAD design documentation from the AE firm throughout the design and construction phases of the project. The initial savings will come from greater accuracy in the quantity takeoff and overall job costing, as well as reducing the number of RFIs that will be required to complete the bidding process. These expected reductions in waste yielded an estimated savings in operating costs for the general contractor of \$9,000 throughout the course of the project (see Figure 8).

**Figure 8 | Step 2 – Estimating the Reduction in Waste for Operating Costs for General Contractors**

	Percent waste reduction factor	Savings per square foot of construction	Instruction summary
<b>Operating costs</b>			
RFI management (design phase)	10%	\$0.01 (\$0.12 × 10 percent)	Input the estimated percentage of RFIs that can be avoided during the design, estimation, and bidding phase through the use of more detailed color construction documentation.
RFI management (construction phase)	10%	\$0.02 (\$0.16 × 10 percent)	Input the estimated percentage of RFIs that can be avoided during the construction phase through the use of more detailed color construction documentation.
Change order management (construction phase)	10%	\$0.03 (\$0.32 × 10 percent)	Input the estimated percentage change orders, by value, that can be eliminated, reduced, or avoided through the use of more detailed color design documentation.
Subtotal		\$0.06	The ROI model calculates an estimated per-square-foot savings.
<b>Total project savings</b>		<b>\$9,000.00</b> (150,000 square feet x \$0.06)	The per-square-foot savings is multiplied by the total project size to yield the total estimated projects savings in operating costs to the general contractor.

Source: Lyra Research, Inc., Color Construction Documents: A Simple Way to Reduce Costs, April 2010

To estimate the potential savings in project costs, we looked at specific case examples to apply to this sample project. From those examples we applied a 6 percent reduction in the estimated cost contingency due to more accurate job costing and lower bids by subcontractors, as well as savings from more accurate coordination of complex mechanical, electrical, and plumbing services. For simplicity, we estimated a 10 percent reduction in the occurrence of change orders based on the reduction in RFIs and assumed an equivalent dollar value in savings. This reduction factor yields a savings of \$1.47 per square foot and a total project savings of \$220,500 (see Figure 9).

**Figure 9 | Step 3 – Estimating the Reduction in Waste for Project Costs for Project Owners**

	Percentage waste reduction factor	Savings per square foot of construction	Instruction summary
<b>Project costs</b>			
Estimation cost contingency	6%	\$1.32  (\$3.3 million × 6 percent ÷ 150,000 square feet)	Input a percent value by which the total estimation cost contingency for the project can be reduced through the use of color construction documentation during the planning and bidding phase for the project. For this example, to accommodate the design intents for specific ceiling heights, which will require penetrations through numerous joists, we can reduce the time and materials required to install the electrical, mechanical, and plumbing services between units through more accurate coordination and compliance review. Net estimated savings is approximately \$75,000, based on time and materials. Additionally, we anticipate saving up to 5 percent for masonry work by providing clear, color coded construction drawings to subcontractors for bids on a series of exterior facades. Net estimated savings is \$120,000. Combined savings of approximately \$195,000 or 6 percent of the estimation cost contingency.
Change order contingency	10%	\$0.15  (\$220,000 × 10 percent ÷ 150,000 square feet)	Input the estimated percentage of change orders that can be avoided through the use of more detailed color construction documentation during the construction phase of building. For this example, we use the 10 percent reduction in change order management expenses from Figure 8 to reduce the total volume and value of change orders that will be required to complete the project. The 10 percent reduction is conservative, equivalent to eliminating one or two change orders prior to construction with a combined value of \$22,000.
Subtotal		\$1.47	
<b>Total estimated projects savings</b>		<b>\$220,500</b>  (150,000 square feet × \$1.47)	The per square foot savings is multiplied by the total project size (150,000 square feet) to yield the total estimated savings in project costs.

Source: Lyra Research, Inc., Color Construction Documents: A Simple Way to Reduce Costs, April 2010

Using a 2D color CAD workflow, we assumed that the capability to produce color CAD construction documentation is already in place, and that rendering color versions of designs for use during the estimation and bidding process would add little, if any, additional cost to general contractors' expenses because the project owners provide the designs via the AE firm. We then factored in the additional cost of color CAD printing that will be required to enable effective collaboration among stakeholders to generate the project savings. We used average cost factors of 0.50 percent and 0.25 percent of the project budget, respectively, for color and black-and-white printing. These factors yield a total net increase in color printing costs of \$55,000 for the project (see Figure 10).

**Figure 10 | Step 4 – Input Color CAD Printing Costs**

	Printing cost factor	Project budget	Total cost per project	Instruction summary
Color 2D CAD (outsource)	0.50%	\$22,000,000	\$110,000	Input cost factors for color and black-and-white printing as a percentage of the total project budget. Based on our research, the respective factors of 0.50 percent and 0.25 percent are consistent averages for capital building projects.
Black-and-white 2D CAD (outsource)	0.25%	\$22,000,000	\$55,000	The model applies the price delta between the color and black-and-white print pricing, discounting the replacement value of black-and-white print.
<b>Net increase in project printing costs</b>	<b>0.25%</b>		<b>\$55,000</b>	

Source: Lyra Research, Inc., Color Construction Documents: A Simple Way to Reduce Costs, April 2010

Subtracting the net printing costs from the gross project cost and operating cost savings yields an estimated return on investment of \$174,500 for the entire project, or \$1.16 per square foot of construction (see Figure 11).

**Figure 11 | The Results – Estimated Net Return on Investment**

	Dollars per square foot of construction	Total dollars per project
Total estimated project savings (Step 2 and 3)	\$1.53	\$229,500
Total color CAD printing costs (Step 4)	(\$0.37)	(\$55,000)
Net estimated return per project	\$1.16	\$174,500

Source: Lyra Research, Inc., Color Construction Documents: A Simple Way to Reduce Costs, April 2010

## CONCLUSIONS AND RECOMMENDATIONS

Applying color construction documents to design-bid-build projects presents a significant near-term opportunity for improving project collaboration and reducing project-related waste. Using conservative factors to estimate the improvement in job costing and estimation as well as the value and impact of change orders and RFIs reveals that there is a theoretically large pool of addressable waste in building projects. Project stakeholders can achieve meaningful cumulative savings by making minimal reductions of 6 and 10 percent, respectively, of only the addressable occurrences of these businesses processes, including the cost of color printing.

### Benefits to Project Owners

Based on the metrics in the example project, for a \$22 million, 150,000 square-foot capital building project, a \$55,000 investment in color construction document printing results in a project savings of \$174,500. This is a 317 percent return on investment in color printing. Converting this to a ratio of 4:1, every incremental dollar spent on color prints would generate \$4.17 in project savings due to more concise collaboration between stakeholders. Project owners benefit further from:

- timely completion and faster productive use of the facility or structure;
- fewer legal expenses required for negotiations or disputes regarding change orders; and
- reduced operation and maintenance cost due to more accurate and detailed color as-built drawings.

### Benefits to General Contractors

The direct benefits to the general contractor are lower when measured in total dollar value—about \$9,000 for our sample project—but are significant in relation to overall profitability. Industry figures for net profitability for construction contractors average between 1 and 3 percent. Overall revenue growth in the United States has been flat for the past 40 years, while the total number of construction contractors has tripled over the same time period [1]. In other words, construction contractors have limited means to grow revenue or profit without acquiring another firm.

- **Revenue:** For a firm operating at 3 percent net margins, a \$9,000 improvement in profit will require an additional \$300,000 in revenue. At 1 percent net margins, a \$9,000 improvement in profit equates to \$900,000 in additional revenue.
- **Turnover of capital:** Construction is a custom-manufacturing process. As in manufacturing, construction contractors benefit by how they can put capital to use and how quickly they can get it back—make a profit—to put it to use again. The analysis in this white paper makes no assumptions regarding reduced project schedules, but the reduced volume of RFIs and change orders will clearly have a positive impact on project schedules. The faster capital can move from one project to the next, the more profit the general contractor can earn in given year.
- **Schedule bonuses:** Depending on the project, general contractors also benefit financially through project bonuses for completing project milestones early or under budget. The ability to accelerate project schedules using more accurate color construction documentation, for example through coordination and scheduling, helps reduce errors and delays, enabling more continuous throughput of subcontractors and supplier assignments.

### Architects and Engineering Firms — The Missing Link

AE firms lack the necessary incentive either to enhance or, in many cases, provide general contractors with color versions of 2D CAD drawings that were drafted in color. At a high level, better education of project owners would help to mitigate this problem. For general contractors, that recommendation begs the questions how and when.

### Recommended Best Practices

When bid requests are issued for a project and it is possible to establish a dialogue, present the owner with the plausible benefits of using color design documents. Maintain and share a portfolio or realistic samples of similar designs and critical drawings, such as mechanical engineering plans, in color as well as black-and-white to illustrate how the quality of color construction documentation can improve project collaboration.

Use the ROI model developed for this white paper as a tool to illustrate areas where improved design documentation will save money for owners compared with the incremental costs of printing color CAD construction documents in color. Emphasize the potential reduction in RFI management costs for the AE firm. This is typically an expense that cannot be billed and one that AE firms would prefer to avoid or reduce.

AE firms will benefit from a reduction in costs associated with RFI management during construction as well as costs for design and construction information verification during the estimation and bidding phase of a project. The NIST estimates that annual costs for RFI management as well as design and information verification for the average AE firm are \$0.05 per square foot and \$0.10 per square foot, respectively. Referring to the sample project in this white paper, if an AE firm can reduce the frequency of RFIs by providing color CAD construction documentation at the same rate as construction contractors for the same 150,000 square feet of building, they would save approximately \$2,250 per project. The savings would come from reduced time spent verifying information, managing and responding to RFIs, freeing valuable engineering resources for more valuable and billable activities. Although AE firms capture higher net margins, about 6 percent on average, they are limited by the same macroeconomic constraints that impact general contractors. From that perspective, AE firms, like general contractors, have limited ability to grow top-line revenues in the U.S., when compared to the inflation rate. Thus, \$2,250 in bottom line expense reductions is equivalent to growing revenues by approximately \$37,000, from a single project.

Once color documentation is secured as a requirement for a project, use general estimates to capture examples of project savings that were made possible through the use of color designs, drawings, and sketches. Examples include avoided or mitigated change orders, improved scheduling and coordination, or reduced material costs that result from more accurate quantity takeoff during bidding and construction. Keep simple summaries of these examples for use in future projects. Use this information to build credibility and a competitive advantage.

## APPENDIX A

### Research Methodology

In conducting this study, Lyra Research gathered information from a variety of secondary sources to develop a clear theory regarding which business processes are the root cause behind weak productivity growth in the AEC industry. In the second phase of the project, we developed a discussion guide and a preliminary ROI model, which we used during interviews with key general contractor employees throughout the United States. We contacted nine general contractors and AE firm representatives and interviewed them in order to determine how BIM and color CAD printing can help reduce or eliminate business process waste throughout the construction process. Respondents from general-contractor businesses were required to be knowledgeable about the use of BIM and/or color CAD systems through prior projects with their current employer. They were also required to be knowledgeable about the types of costs incurred throughout construction, including the qualitative aspects of how processes evolved and wasteful problems arose. Interviewed subjects included chief information officers (CIOs), BIM specialists, and heads of virtual construction departments as well as project executives. Where possible, subjects were responsible for documenting total project costs and either realized savings or realistic potential savings from the implementation of technologies, including color CAD and/or BIM and color technical printing, respectively.

Interviews took place over a six-week period and typically lasted one hour. Respondents were offered an incentive to participate. Following each interview, we followed up with each respondent to verify responses and review the sample ROI model drafted from answers from the initial interview. Regarding the survey sample size, the primary objective of this white paper is to clearly qualify the primary business problems that plague construction and gain a better understanding of how these problems negatively impact project costs. The applied sample size provides a robust source of qualitative data but is not intended to provide a quantitative summary of industry costs.

### Final Notes

The research findings for this white paper yielded some specific information related to project costs. Nonetheless, the primary objective of this project is to create a tool that allows knowledgeable industry participants to readily frame their understanding of real project costs in a simple and realistic manner. Our goal is to create a platform to help general contractors and project owners more clearly assess the possible risk and return of making color documentation more consistently available throughout all phases of a building project. The following facts anchored this research throughout the project:

- traditional design-bid-build projects generate a large amount of waste that negatively impacts projects; and
- the waste in these projects commonly results from inadequate collaboration, based on:
  - limited access to color design data; and
  - the need for more detailed design data.

The waste can be qualified and in many cases quantified through the key business processes that drive the bidding, estimation, and construction phases of building.

### NIST Values

The change-order management metrics of \$0.32 per square foot include the tasks required to initiate, quote, and execute a change order once it is deemed necessary through the preceding RFI process. Since this metric refers to wasted operating expenses on the part of the general contractor, we also factored in the time required to process change orders for payment but excluded waste associated with unpaid or partially paid change orders. Using a general ratio of X:1, in which 1 = the NIST value for RFI management costs for construction, we estimate that change-order management costs are approximately 2:1 compared with the RFI management cost during construction, or \$0.32 per square foot, for a design-bid-build project.

We reviewed these RFI and change-order management metrics with the respondents we interviewed to ensure that they are generally accurate and can be put to practical use when measuring these process costs.

### Glossary

**Building Information Modeling (BIM):** This is the process of generating and managing building data during its life cycle. It typically uses three-dimensional, real-time, dynamic building modeling software to increase productivity in building design and construction. The process produces the building information model (also abbreviated as BIM), which encompasses building geometry, spatial relationships, geographic information, and quantities and properties of building components [7].

**Design-bid-build:** This is a project delivery method in which the agency or owner contracts with separate entities for the design and construction of a project [8].

**Design build:** This is a construction project delivery system where, in contrast to design-bid-build projects, a contract is made with a single entity known as the design builder or design-build contractor for both the design and construction aspects of a project [9].

**Integrated project delivery (IPD):** This is a project delivery method that integrates people, systems, business structures, and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction [10].

**APPENDIX B**

**ROI Model Example – Completed**

	<b>Example</b>
Project value	\$22,000,000
Total square feet	150,000
Project duration (months)	18
Estimation cost contingency	15%
Change order contingency	2%
Change order reduction factor	50%

**Estimated Project Waste without Color Workflow**

	Waste per square foot of construction	Total waste per project of construction
<b>Project costs (construction phase)</b>		
Estimation cost contingency	\$22.00	\$3,300,000
Total change orders	\$2.93	\$440,000
Unaddressable change orders	(\$1.47)	(\$220,000)
Addressable change orders	\$1.47	\$220,000
<b>Subtotal</b>	<b>\$23.47</b>	<b>\$3,520,000</b>
<b>Operating costs</b>		
RFI management (design phase)	\$0.12	\$18,000
RFI management (construction phase)	\$0.16	\$24,000
Change order management (construction phase)	\$0.32	\$48,000
<b>Subtotal</b>	<b>\$0.60</b>	<b>\$90,000</b>
<b>Total addressable project waste</b>	<b>\$24.07</b>	<b>\$3,610,000</b>

**Waste Reduction with Color Workflow and Printing**

	Savings per square foot of construction	Percentage of waste reduction
<b>Project costs (construction phase)</b>		
Estimation cost contingency	\$1.32	6%
Change orders	\$0.15	10%
<b>Subtotal</b>	<b>\$1.47</b>	
<b>Operating costs</b>		
RFI management (design phase)	\$0.01	10%
RFI management (construction phase)	\$0.02	10%
Change order management (construction phase)	\$0.03	10%
<b>Subtotal</b>	<b>\$0.06</b>	
<b>Total estimated project savings</b>	<b>\$1.53</b>	<b>\$229,500.00</b>

Color Printing Costs

	Printing cost as a factor of the project budget	Total cost per project
Color 2D CAD (outsource)	0.50 %	\$110,000
Black-and-white 2D CAD (outsource)	0.25 %	\$55,000
<b>Net increase in project printing costs</b>		<b>\$55,000</b>
<b>Net estimated return per project</b>		<b>\$174,500</b>

Source: Lyra Research, Inc., Color Construction Documents: A Simple Way to Reduce Costs, April 2010

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