

FIT-FOR-PURPOSE TOOLS FOR USING CII BEST PRACTICES AND MANAGING COMPLEXITY

FR-398

Prepared by



Construction Industry Institute

Research Team 398

November 2025

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EXECUTIVE SUMMARY	5
INTRODUCTION	6
1.1 Background On The Problem	6
1.2 Value Of The Project Outcomes	7
1.3 How To Use This Document	8
PROJECT APPROACH AND RESEARCH METHODOLOGY	9
2.1 Best Practice (BP) Primer	9
2.2 Project Complexity Assessment And Management Tool (PCAM 2.0)	11
2.3 Integration Between BP Primer And PCAM 2.0 Tools	15
PROJECT OUTCOMES	16
3.1 BP Primer Tool Use Case	16
3.2 PCAM 2.0 Tool Use Case	18
3.3 Other Potential Use Case Ideas	22
IMPLEMENTATION INSIGHTS	23
CONCLUSIONS	25
APPENDICES	26
Appendix A Detailed BP Primer Tool Development Methodology	26
Appendix B Complexity Survey	31
REFERENCES	34
MEMBER LIST	35

For over four decades, the Construction Industry Institute (CII) has developed a comprehensive body of research and Best Practices (BPs), available through its online resource library. While these resources have demonstrated a positive impact on project outcomes, evidence shows that member organizations are not fully capitalizing on their potential. The vision of RT-398 was to “optimize” the way CII companies leverage this research and apply it in their organizations. Taking a non-traditional research approach, RT-398 focused on synthesizing existing knowledge and translating them into practical, accessible tools that facilitate their adoption and utilization. To accomplish this goal, two separate complimentary Excel-based Fit-for-Purpose (F4P) tools were developed that can help users better understand the BPs and manage project complexity:

- The BP Primer tool provides executive-level summaries at both the BP and report levels, highlighting key actionable insights (“golden nuggets”) and detailed, phase-specific action items for more efficient implementation.
- The Project Complexity Assessment and Management (PCAM) 2.0 tool enhances the original RT-305 complexity tool by streamlining the assessment and scoring process, consolidating complexity attributes, and incorporating informative visual aids such as radar diagrams and complexity rating gauges.

These tools offer a scalable and integrated, user-focused framework to advance CII research adoption, strengthen project planning and risk management, and enable proactive complexity mitigation. Use cases for each tool are provided demonstrating their value at both the project and company level. Additionally, a Power BI version of the BP Primer tool has been created that allows users easier navigation capabilities to find information that matters to them. A roadmap is also included, guiding users through downloading, deploying, and using the tools effectively.

1.1 Background on the Problem

The construction industry is currently facing multiple challenges such as escalating material costs, disruptions in the supply chain, and growing demand for efficiency in scheduling and safety. For over four decades, the Construction Industry Institute (CII) has been at the forefront of industry research and development, focusing on improving construction processes and methodologies. However, the vast amount of research produced by CII has created challenges in accessibility and practical application for industry members. CII recognized the need for tools that allow efficient navigation, understanding, and application of its research across different project types and complexity levels.

CII formed Research Team (RT) 398 with the directive to create Fit-For-Purpose (F4P) tools that facilitate effective access to its extensive body of knowledge. The main objective of this research was to bridge the gap between research and implementation by delivering streamlined, user-friendly tools that guide users directly to relevant insights. Figure 1(a) provides a conceptual illustration of the current state for extracting knowledge and Figure 1(b) shows the new ‘easy button’ approach made possible by the new F4P tools. The Best Practice Primer tool provides executive-level summaries at the BP and report levels by identifying actionable insights (“golden nuggets”) and detailed action items for more efficient implementation by project phase. The Project Complexity Assessment and Management (PCAM) 2.0 tool enhances the original RT-305 complexity tool by streamlining the assessment and scoring process, consolidating complexity attributes and introducing informative visual aids such as radar diagrams and complexity rating gauges.

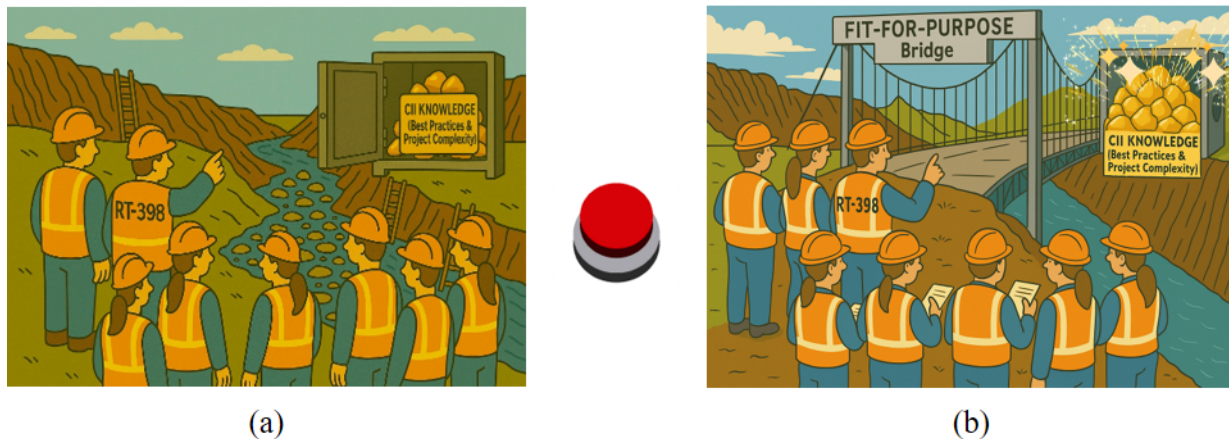


Figure 1. (a): Current Approach; (b) Our Approach

1.2 Value of the Project Outcomes

Quick and efficient access to structured research enables project managers to anticipate and mitigate potential problems before they escalate. Staying informed on the latest research advancements in construction and project management equips teams to enhance safety, productivity, and client satisfaction by delivering high-quality results on time and within budget. The Best Practice Primer tool addresses these needs by providing a structured approach to navigate through CII's Best Practices (BPs), offering executive summaries, phase-specific golden nuggets, detailed action items (DAIs), with hyperlinks to full research reports. By layering information from high-level insights to detailed guidance, this tool reduces information overload, enhances decision-making, and improves stakeholder communication across all phases of a project.

The BP Primer's format allows users to:

- Access executive summaries and insights,
- Link directly to detailed reports,
- Navigate Best Practices across different project phases,
- Reference key points even when away from computers, ensuring that insights are usable in both field and office settings.

Project Complexity refers to the degree of difficulty involved in managing and executing a construction project. This complexity can arise from various factors, including technical, organizational, and environmental elements that influence the project's scope, schedule, cost, and quality. The PCAM 2.0 tool complements the Best Practice Primer tool by simplifying project complexity assessment. It reduces cognitive load through binary scoring, phase-based evaluations, and visual tools such as radar diagrams and complexity rating gauges. Feedback from diverse industry stakeholders has confirmed that PCAM 2.0 meets evolving needs for proactive complexity management, significantly improving planning, execution, and risk mitigation across capital facility projects.

Both tools extend the accessibility of CII research in both planning sessions and field operations. This work provides foundational support for the ongoing development of complexity management and best practice application tools, helping to improve project delivery across the construction industry.

1.3 How to Use this Document

This document provides a structured pathway for users to engage with CII's research findings in extensive detail. Whether it's staying informed about the latest construction trends or best practices in project management, having quick access to reliable research findings allows managers to optimize processes and improve overall project outcomes. When project managers can swiftly share relevant research knowledge and insights with stakeholders, from subcontractors to designers, it creates a more efficient workflow, minimizes errors, and promotes the success of construction projects. A brief description of the fit-for-purpose (F4P) tool development is provided along with use cases that demonstrate their value. Furthermore, a roadmap is provided for downloading and implementing the tools.

RT-398's vision was to "optimize" the way member companies can leverage CII research in their organizations. A "non-traditional" research approach was used to summarize existing knowledge and "bridge" this research into practical, accessible tools that facilitate their adoption and utilization. The research team was divided into three subteams with specific directives as follows:

1. **Best Practices:** Develop a BP primer tool that extracts golden nuggets and detailed action items for each Best Practice in the CII resource library.
2. **Project Complexity:** Refine the original (RT-305) tool to create a more streamlined way to assess and manage project complexity.
3. **Artificial Intelligence:** Leverage artificial intelligence (AI) to support the development of the Best Practices and Project Complexity Tools.

2.1 Best Practice (BP) Primer

The BP Primer development employs a hybrid methodology, integrating qualitative analysis with a Retrieval-Augmented Generation (RAG) framework and large language models (LLMs) to extract actionable insights (“golden nuggets”) and detailed action items (DAIs) from several CII publications associated with BPs. We applied the same approach to generate BP-level executive summaries and frequently asked questions (FAQs) by synthesizing key information from multiple reports and implementation resources within each BP. Additionally, report-level takeaway summaries were created by compiling each report’s high-level summaries, golden nuggets, and DAIs into Word documents. All features were systematically organized within an Excel-based platform, complemented by project phase mapping and hyperlink navigation for ease of use.

The methodology for developing the BP Primer tool included:

- **Data Collection:** A total of 54 CII publications associated with BPs and their associated tools were collected, with the CII Best Practices Guide IR166-3 (CII, 2022) serving as the primary reference.
- **Best Practice Definition:** A CII Best Practice is defined as a “process(es) or method(s) that, when executed effectively, lead to enhanced project performance” and must be validated through extensive industry use (CII-166, 2017).
- **Actionable Insights Extraction:** Key insights (“Golden Nuggets” or GNs) were extracted through a hybrid method combining qualitative review and RAG-driven LLM approaches.
- **Detailed Action Items (DAIs):** GNs were expanded into DAIs using the RAG-driven LLM approaches
- **Executive Summaries and FAQs:** Each BP was further supported by a summary and frequently asked questions section using the RAG-driven LLM approaches.
- **Takeaway Summaries:** Each report was further supported by a takeaway summary by compiling report-level summaries, GNs, and DAIs into a Word file. The collected information was systematically structured into an Excel platform with the following organization:
- **Horizontal axis:** Project phases (with definitions in “Note” fields) + project delivery method (determine when a contractor should get involved).
- **Vertical axis:** 17 Best Practices, with expandable layers:
 - **Layer 1:** Executive summary (linked to Word doc)
 - **Layer 2:** Full report list + high-level summary + takeaway summary (linked to Word doc) + report links
 - **Layer 3:** GNs by project phase + tool links
 - **Layer 4:** DAIs associated with GNs

Initially, the research team collected 54 BP reports and their associated tools in PDF format. The CII Best Practices Guide IR166-3 (CII, 2022) served as the foundational reference, supplemented by executive summaries within the reports. A hybrid methodology, integrating qualitative analysis with a Retrieval Augmented Generation (RAG)-enabled LLM framework, was used to extract critical insights known as “golden nuggets” (GNs) from each BP report. These GNs were expanded into detailed action items (DAIs) using the same framework. Final deliveries for each BP included an executive summary and FAQs. Final deliveries for each report included a takeaway summary.

All insights were systematically structured into an Excel-based knowledge management platform organized by project phases (horizontal axis) and best practices (vertical axis), with hyperlinks enabling deeper exploration (Figure 2).

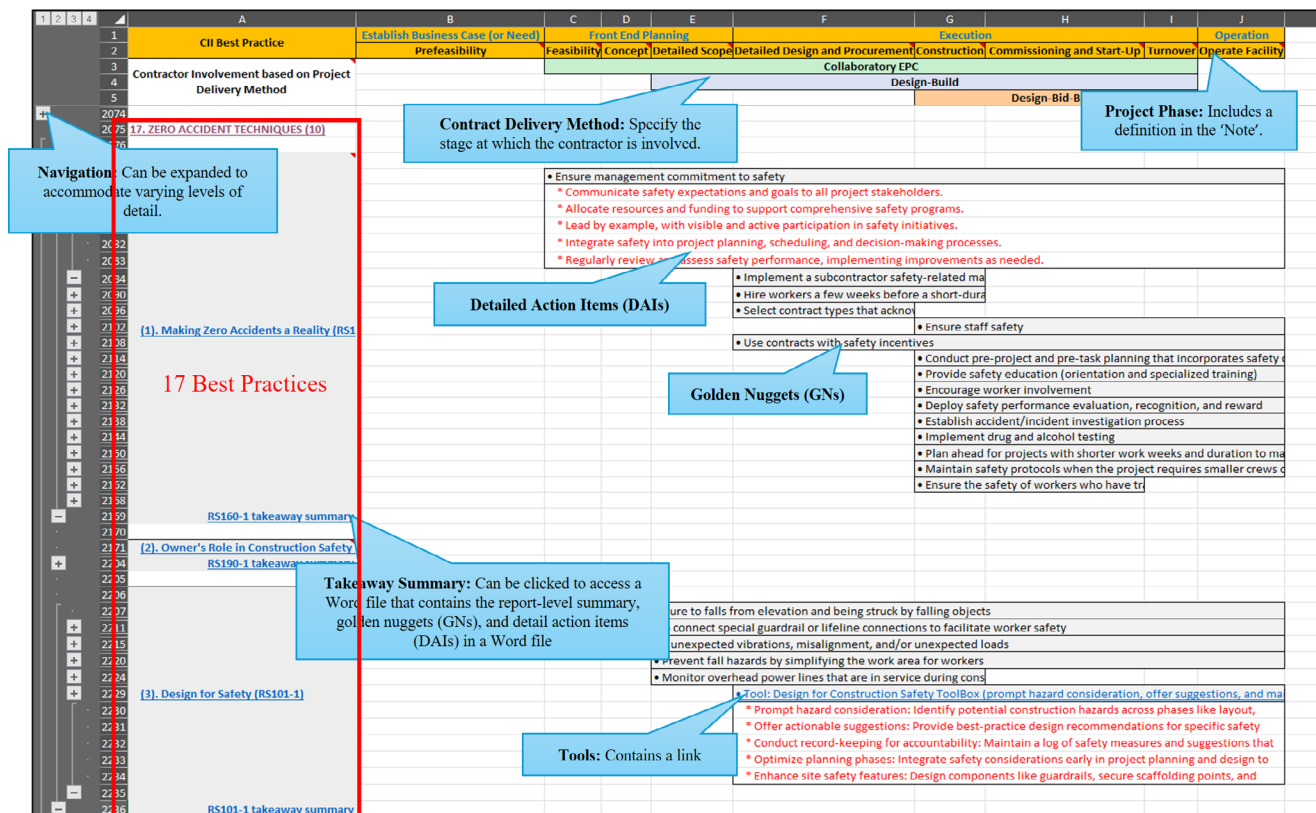


Figure 2. Best Practice (BP) Primer tool

Functional Validation Process:

- LLM-as-a-Judge: LLM models are used as a judge to provide scores for the clarity, structure, and actionability of the BP Primer tool contents.
- Classroom Review: The BP Primer tool was brought to the CII BP course at NC State University. Students were asked to manually review the tool and offer feedback.
- SME Review: Reviews were conducted by industry experts and academic advisors.
- Survey Feedback: Structured surveys were conducted with RT-398 team members, academic reviewers, BP course students, and CII Communities for Business Advancement (CBA) participants.
- Real-World Application Testing: The tool was validated in practical settings primarily within team member companies.

2.2 Project Complexity Assessment and Management Tool (PCAM 2.0)

The Project Complexity Assessment and Management (PCAM 2.0) tool provides a streamlined and practical approach to assess project complexity and identify appropriate management strategies. The tool was restructured to improve both usability and industry adoption using the original research from RT-305. PCAM 2.0 reduces the number of complexity indicators from 37 to 14 and simplifies the scoring system from a 9-level scale to a binary format. It offers four adaptable assessment approaches: a streamlined general assessment, phase-based assessment, complexity area-based assessment, and detailed general assessment. Visual aids such as a radar diagram and complexity rating gauges enhance the user experience, while management strategies have been condensed for faster comprehension and decision-making (Figure 3).

Designed as an Excel-based tool, PCAM 2.0 is both accessible and easy to deploy in real-world project environments. It requires minimal training with an intuitive, user-driven structure that enables flexible implementation at any project stage. Users can select complexity attributes and indicators tailored to their specific project context (hence F4P), receiving customized management strategies in return. The validation process confirmed notable improvements in usability, accessibility, and applicability, reinforcing PCAM 2.0's value as a scalable solution for complexity management in capital facility projects.

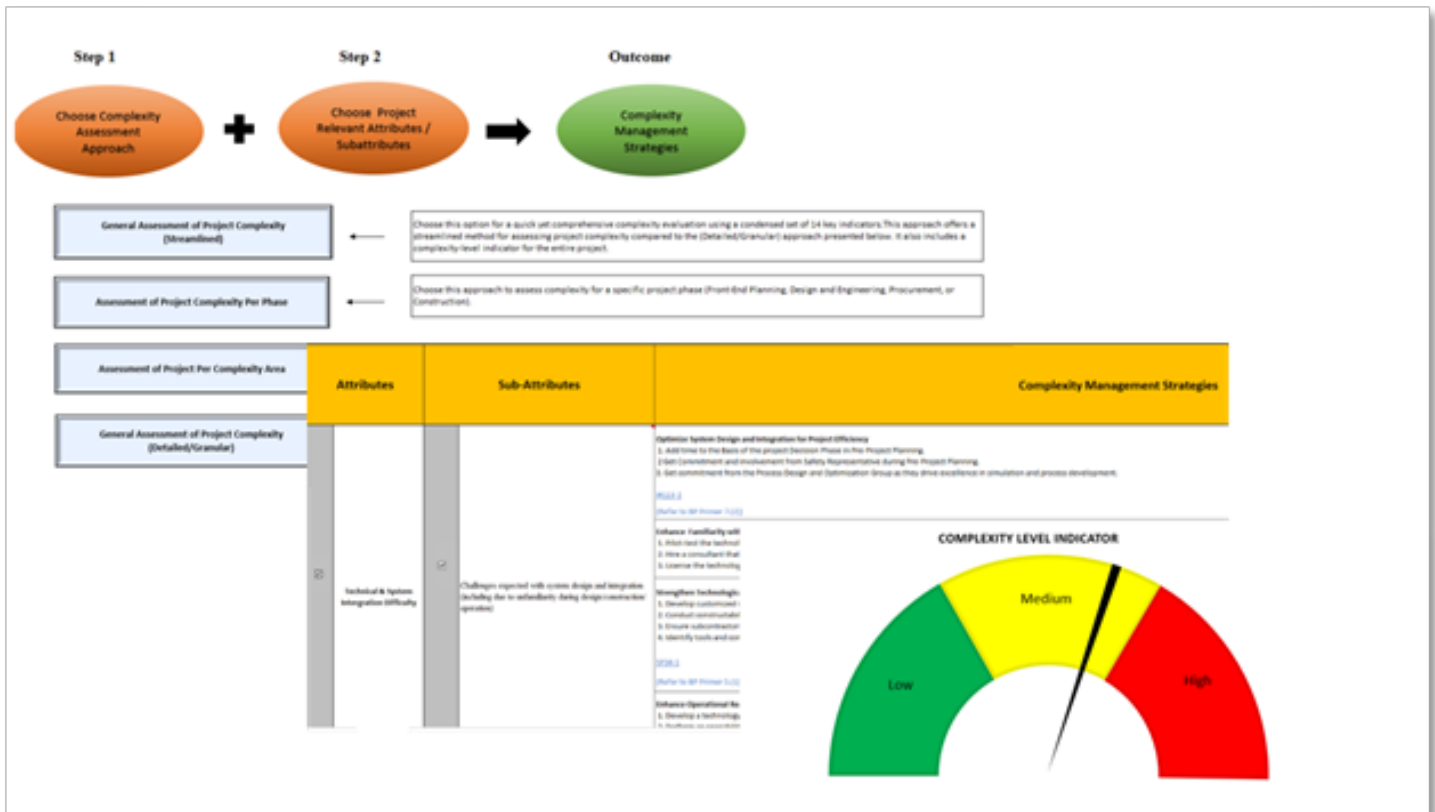


Figure 3. Project Complexity Assessment and Management (PCAM 2.0) Tool

Several enhancements were introduced to improve usability and adoption:

- **Complexity Indicators (Sub attributes) Simplification:** In the streamlined approach, the original 37 sub attributes were consolidated into 14 grouped indicators to streamline the assessment process.
- **Scoring System Update:** A binary selection process was used to replace the previous 9-level scoring and minimize the cognitive load on users.
- **Integration of Cognitive Psychology Principles:** Design principles were applied to the tool's structure to reduce mental burden and improve user decision-making such as reducing memory load, minimizing attentional resources, and aligning the tool with mental models.
- **User Experience Enhancements:** Visual tools such as a radar diagram and complexity rating gauges were integrated to make complexity assessment results easier to understand as shown in Figure 4.

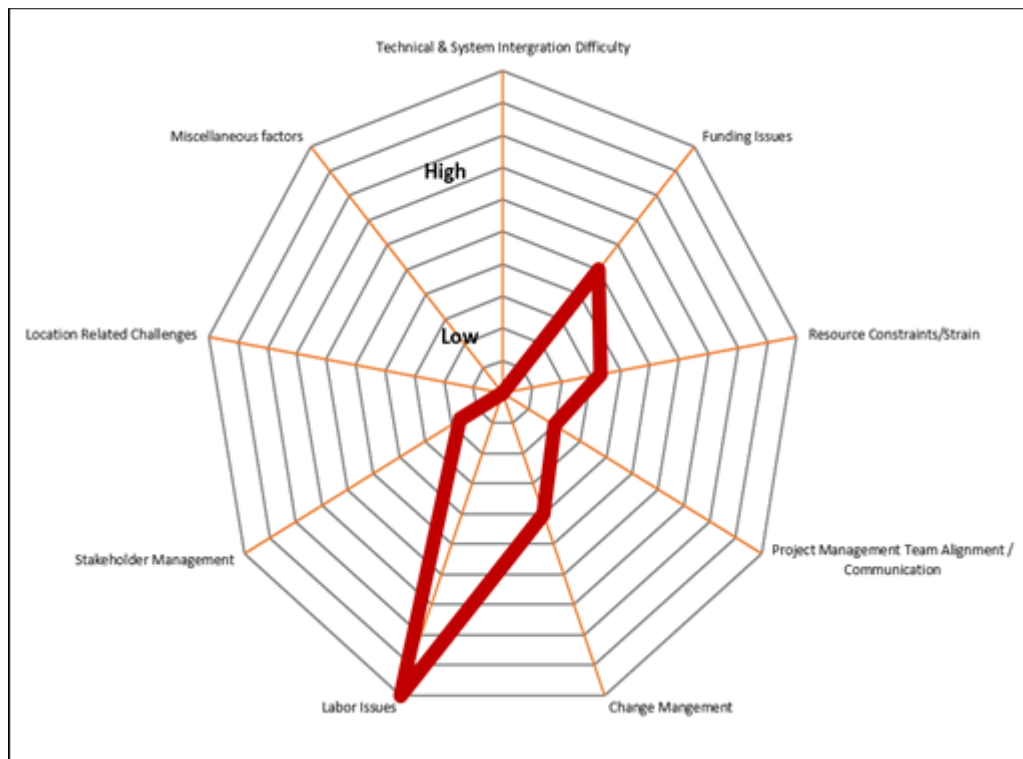


Figure 4. Radar Diagram

Validation Process:

A structured three-step opinion-based validation process was implemented to ensure that the PCAM 2.0 tool is effective, user-friendly, and applicable in real-world capital facility projects. This process emphasized continuous feedback and iterative improvement based on the input of practitioners and experts from both academia and industry.

- **Initial Evaluation with Complexity Subteam Members:** In this first step, members of the Complexity Subteam assessed the tool for initial usability and logic consistency. Their feedback identified key issues to address before broader distribution.
- **Extended Evaluation with RT-398 Members:** After necessary modifications were made, the tool was evaluated by the full RT-398 research team who were not directly involved in the development of PCAM 2.0. RT-398 included industry experts from various disciplines and roles (e.g., contractors, and owners) to ensure diverse perspectives. Feedback focused on effectiveness, practicality, and industry alignment.
- **Industry-Wide Evaluation with CII Members and SMEs:** The final validation step involved members of the Construction Industry Institute (CII), including Communities for Business Advancement (CBAs). This external review allowed for unbiased assessments from professionals not involved in the tool's development. Their input addressed real-world applicability, clarity, and strategic value.

Each round of feedback was followed by tool modification to integrate suggestions. This iterative approach ensured that PCAM 2.0 became more robust, intuitive, and aligned with the actual complexity management needs of industry users. A side-by-side comparison with the original PCAM tool also confirmed that the updated version improved usability and streamlined decision-making without compromising rigor.

2.3 Integration Between BP Primer and PCAM 2.0 Tools

To enhance the depth and practicality of the tools, the PCAM 2.0 tool was intentionally designed to complement the Best Practices (BP) Primer. While PCAM 2.0 helps users identify relevant complexity attributes and provides tailored management strategies, the BP Primer offers detailed, actionable items rooted in CII's 17 formal Best Practices. As shown in Figure 5, references like "Refer to BP Primer 7.(1)" are embedded directly within PCAM 2.0's "Complexity Management Strategies" column. These references guide users to specific reports within the BP Primer that allows them to explore aligned strategies in greater depth. PCAM 2.0 flags areas of concern and provides strategic management strategies, while the BP Primer supplies the expanded frameworks and tools needed for execution. Together, they offer a holistic and complementary system for improving project outcomes.

	Attributes	Sub-Attributes	Complexity Management Strategies
<input checked="" type="checkbox"/>	Funding Issues	<input checked="" type="checkbox"/> CI-7 Multiple Funding Phases (Gates) from Concept to Project Completion <input type="checkbox"/> CI-8 Significant Effort Required to Secure Project Funding	1. Define and convey the criteria and guidelines for every funding source. 2. Comprehend and articulate essential deliverables for each project decision gate, establishing their connection to funding needs. 3. Clarify roles, responsibilities, and approval authority for obtaining funding. (B212-2) (Refer to BP Primer 7.(1))

Figure 5. Radar Diagram

Functional Validation

Two use cases are provided that validate the functionality of the Best Practice Primer and Project Complexity Assessment and Management (PCAM) 2.0 tool. Other use case ideas are also provided.

3.1 BP Primer Tool Use Case

The Black & Veatch (BV) use case represents the arduous journey they traveled to ensure their Advanced Work Packaging (AWP) program was thoroughly planned and implemented in line with CII Best Practices. In 2015, BV initiated the development of a comprehensive AWP program, drawing on extensive CII research that included insights from Research Teams RT-272 and RT-319. They engaged with internal stakeholders, hired a third-party consultant, and aligned efforts with the Lean and Project Controls groups. This effort resulted in the creation of implementation handbooks, guides, and a home-grown software program called Package Manager to support AWP implementation.

Once the program was ready, BV piloted the Work Face Planning component and tool on three direct-hire projects. To Black & Veatch then participated in the Research Team 365 effort around identifying barriers to AWP implementation and promoting its use. The scope was expanded to include Engineering and Procurement, and the complete AWP program using the Package Manager Tool was successfully piloted on a large EPC project in 2019 (Figure 6).



Figure 6. Black & Veatch Advanced Work Packaging Handbook and Brochure

After a review of the BP Primer tool with some of the AWP development team leadership, the response was overwhelmingly positive. The feedback received found the information to be streamlined and accessible, the golden nuggets are right on target, the details are great for program development and implementation, and the summary reports are valuable for communication to leadership and professionals. Finally, participants estimated that the use of the BP Primer tool would have saved BV a lot of time and frustration digging through an overwhelming number of documents to find what was needed. The takeaway was, “We wish we knew then what we know now!”

Going forward, this fit-for-purpose research and resulting BP primer tool will help optimize the next efforts to develop and improve processes, procedures, programs, and training at Black & Veatch in line with CII best practices. Figure 7 demonstrates an example of how the BP Primer will be used to improve and refresh BV’s Constructability Program. CII Best Practices were used in the original development of the Constructability Procedure which served as the foundation for several targeted training programs. The effectiveness of the training and implementation of the overall Constructability Program is measured with a scorecard that then feeds the cycle of continuous improvement. With the new BP Primer tool, teams can now check to ensure alignment with industry best practices, allowing the ability to drill into the information with precision and address issues that are uncovered, continuously improving BV’s procedures, training, and programs.

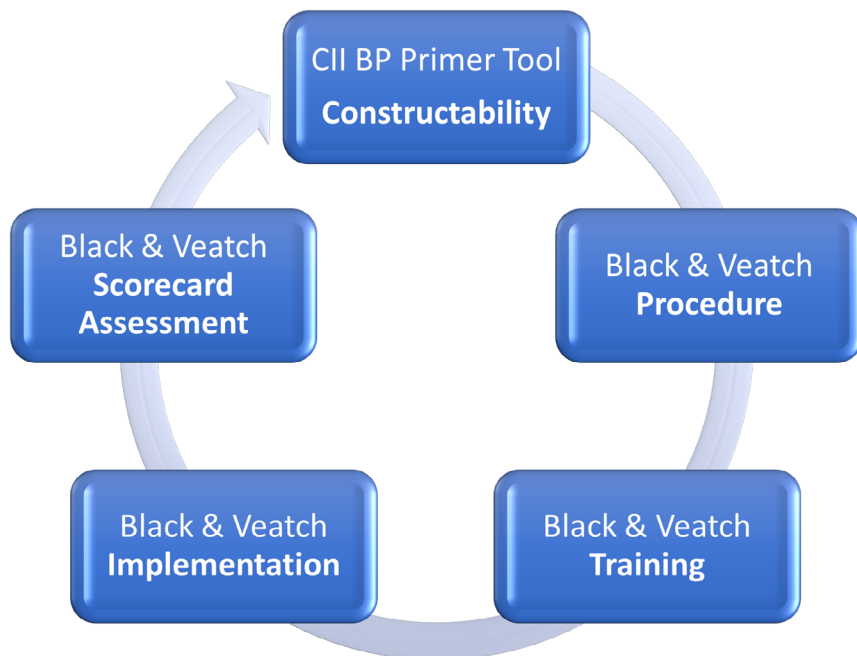


Figure 7. BP Primer Tool Use for Continuous Improvement and Best Practice Alignment

3.2 PCAM 2.0 Tool Use Case

An assessment was conducted at the Tennessee Valley Authority (TVA) of a solar construction project using the streamlined general assessment method. Figure 8 shows an image of the project. Due to the confidential nature of the project, specific project details are kept intentionally vague. A project manager of a large-scale solar construction project was engaged to experiment with the complexity tool. The intent was to utilize the tool and identify mitigation strategies that the PCAM 2.0 tool recommends for the project. The streamlined method was used in the analysis to help identify those attributes that exhibit some sense of complexity or challenge to achieving project success.



Figure 8. TVA Solar Project Use Case

During the assessment, several areas of significant project complexity were identified, including:

- System Integration
- Labor Resources
- Stakeholder Management (Permitting, approvals)
- Out of sequence work required for construction continuity
- Communication and public relations messaging

Applying the PCAM 2.0 tool allowed the project team to identify management strategies aligned with each complexity area. The recommended mitigation strategies included:

- Strengthen technological expertise in Construction Management; CII - Constructability Implementation Guide
- Enhance Local Craft Labor recruitment, training and workforce stability; CII - The Construction Productivity Handbook
- Streamline design approvals through early engagement and proven precedents; CII - Compass: Communications Project Assessment
- Minimize construction workarounds through proactive procurement and schedule integration; CII - A Guide to Construction Rework Reduction
- Align project execution with long-term organization growth and strategic success; CII - Development and alignment of project objectives and success

Given the project's high complexity rating (Figure 9), our next step was to use the PCAM 2.0 tool to find tips for applying those strategies and use the additional references to navigate the BP Primer tool. This allowed users to quickly identify key insights tied to recommended management strategies (Figure 10).

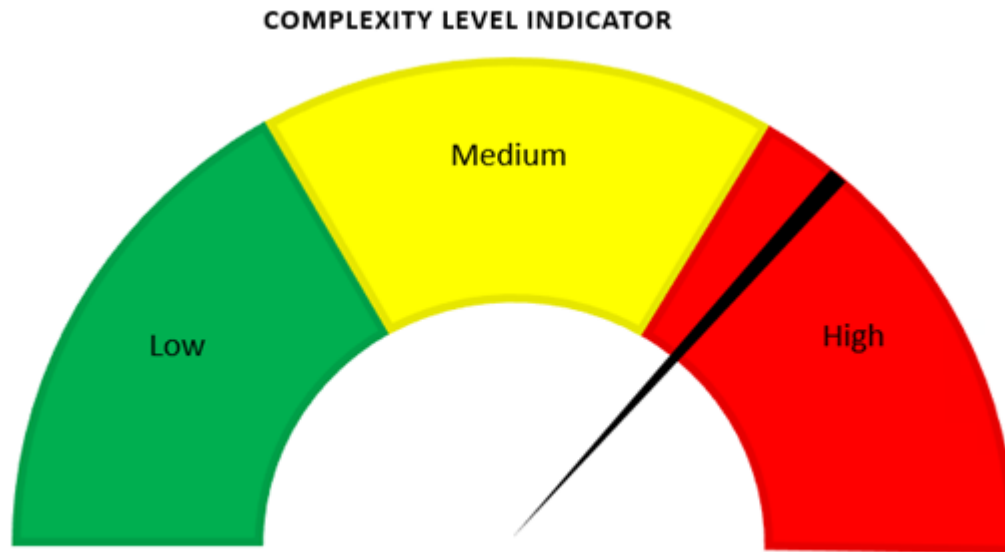


Figure 9. Project Complexity Rating

The tool gave us CII best practice **strategies for mitigating** those complexities with:

- Enhancing Local Craft Labor recruitment, training and workforce stability
- Streamlining design approvals through early engagement and proven precedents
- Minimizing construction workarounds through proactive procurement and schedule integration
- Aligning project execution with long-term organizational strategy
- Strengthening technological expertise

<input checked="" type="checkbox"/>	Technical & System Intergration Difficulty	<input checked="" type="checkbox"/>	Challenges expected with system design and integration (including due to unfamiliarity during design/construction/operation)	<div> <div> 1. Purchase the technology. 2. Hire a consultant that has experience with the technology to assist in design. 3. License the technology. </div> <div style="border: 1px solid red; padding: 5px;"> Strengthen Technological Expertise in Construction Methods and Execution 1. Develop customized specification for the technology. 2. Conduct constructability reviews with a comprehensive project team presentation. 3. Ensure subcontractors undergo a rigorous prequalification assessing their craft labor's ability to employ planned construction practices. 4. Identify tools and consumables that could harm the process if used in construction. </div> </div> <div> SP34-1 (Refer to BP Primer 5.(1)) </div>
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Figure 10. Management Strategies for Addressing Project Complexity

From our analysis, we identified five key areas that required deeper evaluation to ensure a solid plan for mitigating challenges. PCAM 2.0 tool provides mitigation tips based on past CII research, along with a direct link to the full research report they originate from. For instance, Figure 11 includes a link to “SP34-1,” which contains specific guidance on strengthening technological expertise.

Our next step was to review the provided map and pointers to the BP primer tool, leveraging that tool to navigate CII’s extensive research and find insights tailored to our needs. By utilizing the BP Primer tool references linked through the PCAM 2.0 tool (refer to Figure 11), users could seamlessly access detailed guidance, supporting documents, and direct links to best practices on the CII website. This demonstrated PCAM 2.0’s ability to diagnose complexities while connecting users to proven, research-backed solutions.

Technical & System Integration Difficulty

Challenges expected with system design and integration (including due to unfamiliarity during design/construction operation)

Strengthen Technological Expertise in Construction Methods and Execution

1. Develop customized specification for the technology.
2. Conduct constructability reviews with a comprehensive project team presentation.
3. Ensure subcontractors undergo a rigorous prequalification assessing their craft labor's ability to employ planned construction practices.
4. Identify tools and consumables that could harm the process if used in construction.

SP34-1

(Refer to BP Primer 5.(1))

5. CONSTRUCTABILITY (1)

(1). Preview of Constructability Implementation (RS34-2)

RS34-2 takeaway summary

Constructability Implementation Guide, Second Edition

PUBLICATION NO: SP34-1 TYPE: Guidelines/Recommendations

PUBLICATION DATE: Dec 01, 2009 PAGES: 154

RESEARCH TEAM: RT-034

Free Member Download Order Now

- * Promote constructability for efficiency: Implementing constructability can significantly reduce project costs and improve project efficiency.
- * Follow the constructability roadmap: The guide outlines a roadmap with six milestones to guide the project team.
- * Utilize constructability tools: The guide provides 17 tools to evaluate, plan, and manage constructability.
- * Focus on training and support: Emphasis on training, team-building, and management.
- * Document lessons learned: Maintaining a lessons learned database is essential for future projects.

Figure 11. Management Strategies for Addressing Project Complexity

3.3 Other Potential Use Case Ideas

Additional potential use cases for both tools include education, training, and process improvement. The BP Primer tool can augment existing educational project management materials and help train the next generation of workforce. The BP Primer tool allows users to open one file and explore what CII has to offer as it pertains to the Best Practices and relevant tools. The PCAM 2.0 tool can also be used to understand the important complexity indicators to consider for a project and offer strategies for managing this complexity.

Related to process improvement, the BP Primer tool provides a convenient “one-stop-shop” for obtaining BP information during any project phase. For example, if you have a specific issue on your project, you can open the BP Primer tool and determine if any BPs relate to your issue and see what golden nuggets and action items can be implemented during the project’s current phase. This information can help users adjust existing processes that have performance gaps or if they want to audit and ensure compliance with industry standards. If an organization wants to implement a new Best Practice (e.g., modularization), the BP Primer tool can assist in providing critical CII data to build a business case or help create an implementation plan. The PCAM 2.0 tool can also be used to help organizations sharpen their project complexity assessment guidelines and offers links to key CII research that can help mitigate their complexity issues.

Installation Instructions

The BP Primer tool is available for download in both Excel and Power BI versions from the CII website as a compressed .zip file. For the Excel version, users should right-click the downloaded .zip file and select “Extract All...” (Figure 12a), then choose a preferred directory on their computer. Ensure that all subfolders and associated files (Figure 12b) are extracted into the same directory to enable full access (executive summaries, takeaway summaries) and functionality of the tool. Once extracted, users can open the “BPPrimer” Excel file and start using the BP Primer tool independently.

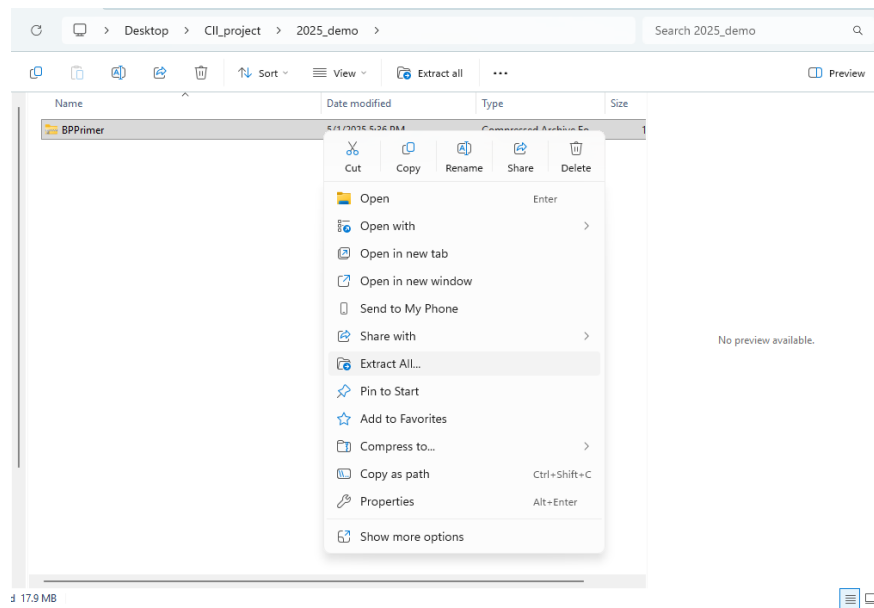


Figure 12. (a): BP Primer File Extraction from Zip Folder

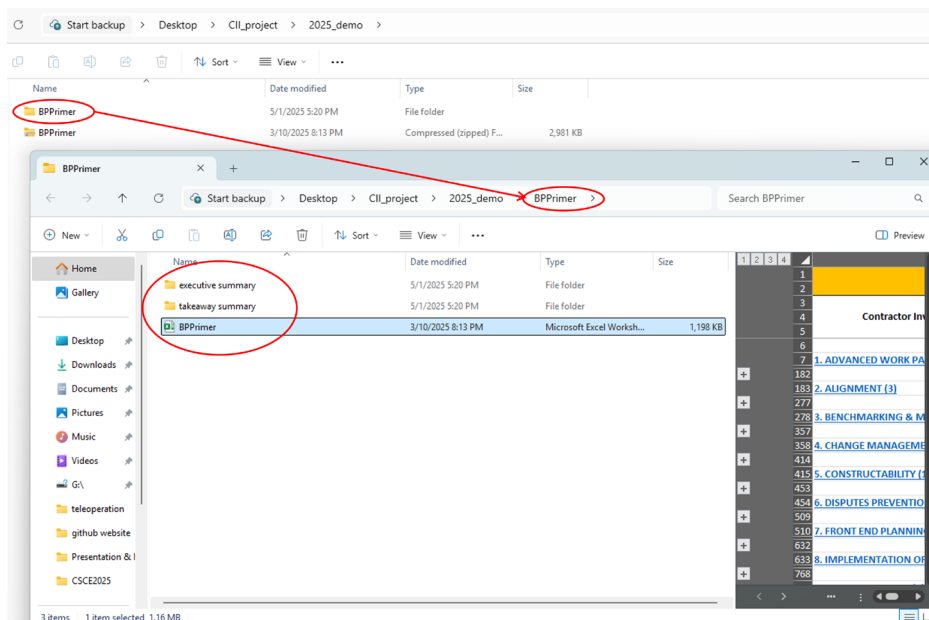


Figure 12. (b): File Storage Requirement in Same Folder for Excel Version

To use the Power BI version, users must first install Power BI Desktop, a free Microsoft application available online. After installing the software, similarly, users should extract the downloaded .zip file by selecting “Extract All...” to a preferred location on their computer to ensure all files are stored in the same folder (Figure 13a). Once extracted, users can open the Power BI file titled “CII BP Primer” (Figure 13a), which will launch the Power BI interface (Figure 13b). From there, users can explore and interact with the BP Primer tool independently.

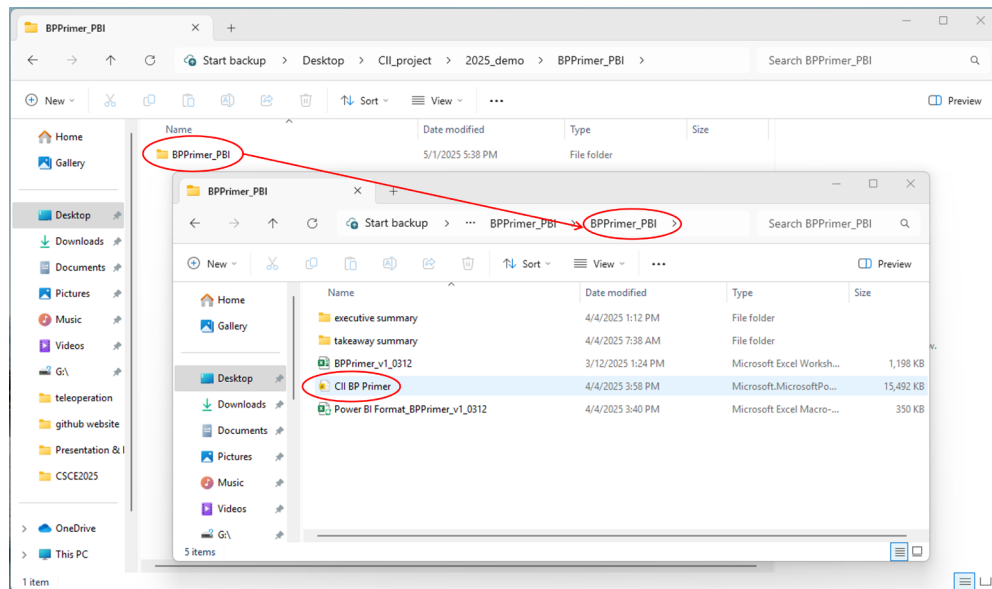


Figure 13. (a): File Storage Requirement in the Same Folder for Power BI Version

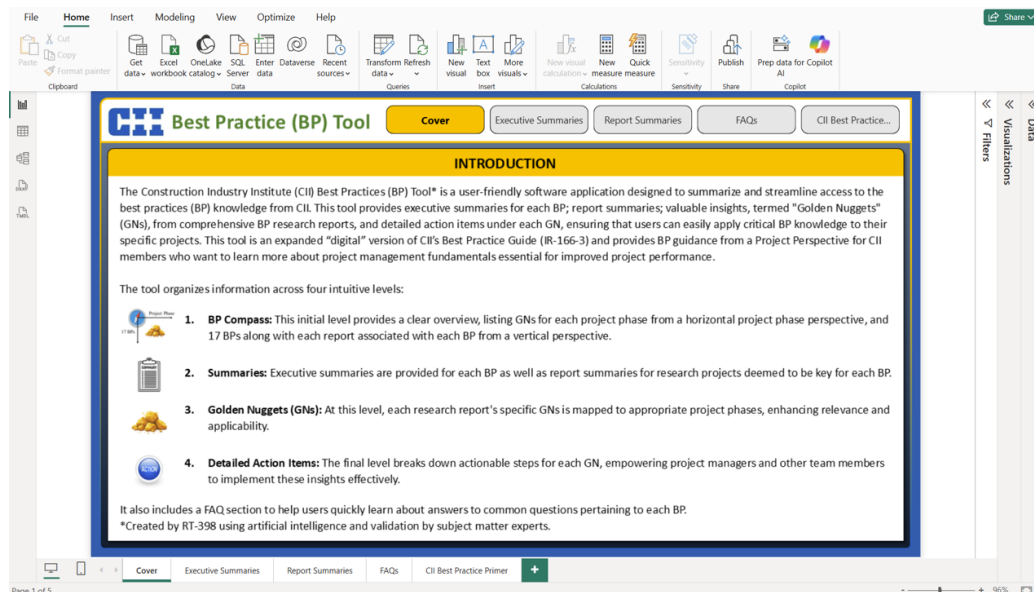


Figure 13. (b): The Default Power BI Interface When Selecting A File

This research fills an important gap by providing tools that increase the visibility and use of CII research for member companies. The main objective of this research was to develop fit-for-purpose tools that allow industry members to more efficiently access key research in the CII resource library. The Best Practice Primer tool provides executive-level summaries at the BP and report levels and identifies actionable insights (“golden nuggets”) and detailed action items for more efficient implementation across project phases. The Project Complexity Assessment and Management (PCAM) 2.0 tool enhances the original RT-305 complexity tool by streamlining the assessment and scoring process, consolidating complexity attributes, and introducing informative visual aids such as a radar diagram and complexity rating gauges. These tools offer a scalable, integrated, user-focused framework to advance CII research adoption, strengthen project planning and risk management, and enable proactive complexity mitigation. Use cases for each tool are provided, demonstrating their value at both the project and company level. Additionally, a Power BI version of the BP Primer tool has been created that allows users easier navigation capabilities to find information that matters to them. A roadmap for how to use the tools is included, which describes how to download and implement the tools. Our goal is for users to become familiar with both the tools and facilitate company-wide adoption.

Appendix A: Detailed BP Primer Tool Development Methodology

RAG Dataflow: Retrieval Augmented Generation (RAG) serves as one of the foundational methods to pull out key insights from CII research reports. As shown in Figure 14, the RAG framework consists of several key stages. First, data from CII reports undergoes a series of preprocessing steps, including data loading, parsing, and cleaning to ensure a structured format. The processed text is then segmented into sub-chunks, which are subsequently converted into vector representations using an embedding model. These vectorized representations are stored in a vector database for efficient retrieval. Once a user query is received, it undergoes the same preprocessing and vectorization pipeline, transforming it into a query vector. This vector is then compared against the stored vectors using cosine similarity, enabling the system to retrieve the most relevant information from the database. Finally, the retrieved information serves as the context that is fed into the LLM, facilitating summarization and response generation tailored to the user’s query.

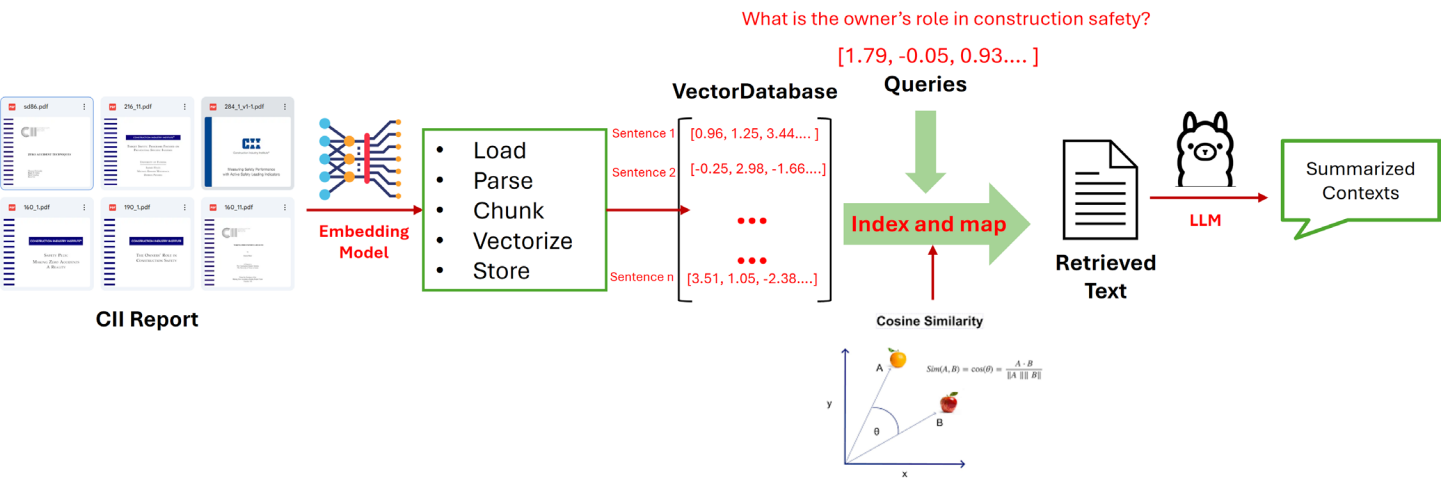


Figure 14. Retrieval Augmented Generation (RAG) Data Flow

Prompts Engineering: Prompts are mainly drafted for content summarization and generation. Elaborative prompts played an important role in generating reliable outcomes. This research meticulously crafts detailed prompts to guide LLM behaviors in generating expected outputs.

- **Prompts for summarizing Golden Nuggets (GNs):** Based on the provided file, summarize the key information using no more than five bullet points. Each bullet point sentence should start with a verb, no more than 30 words, concise, complete, and representative. Each bullet sign should be “*”.
- **Prompts for summarizing Detailed Action Items (DAIs) for each GN:** Based on the provided file, what would be the detailed action items for “GN Title”? Summarize from the construction project’s perspective. You should summarize in no more than five bullet points, each bullet point sentence should start with a verb. Each bullet point should be concise, complete, and representative. Each bullet point should be less than 30 words. The bullet point sign should be “*”.
- **Prompts for summarizing key contents for research tools:** Help me summarize this document in less than five bullet points. Each bullet point should be concise and representative, starting with a verb. Each bullet point should represent the key takeaways of this report and be less than 25 words.
- **Prompts for generating an executive summary for each BP:** Based on the provided file, write me an executive summary for “BP Title” using the “Abstract” textual information. The executive summary should be representative and comprehensive, highlighting the key takeaways we should know for knowledge of “BP Title.” Write a cohesive and concise summary. When writing the summaries, also quote which “Research #” it is so I can track sources. Do not separate your writing by each “Research #”.
- **Prompts for generating FAQs for each BP:** Based on the provided file, help me generate five FAQs for “BP Title” using the “Abstract” textual information. The FAQs should be representative and comprehensive, highlighting the key takeaways we should know for knowledge of “BP Title.” After generating the FAQs, provide suggested answers for each FAQ. The answers for each FAQ should be concise. Make sure the answers came from diverse “Research #” to enhance comprehensiveness. Please also list which “Research #” for each answer that you generated so readers can track sources. *For example, an expected FAQ and answer format is:*
 - “FAQ1: xxxx
 - Answer: xxxx
 - Source: Research #”

LLM-as-a-Judge: This research deployed the LLM-as-a-Judge method as one of the validation methods to evaluate the quality of summarized GNs and DAIs. By the time the research was conducted, our study primarily utilized Llama 3 for summarization while employing the more advanced Phi-3 model as a judge, given its superior performance over Llama 3. Since data privacy is a critical issue for CII, all models were implemented locally. The evaluation process adheres to the RAG framework, wherein each research report is uploaded to the Phi-3 model for assessment. To ensure a structured and rigorous evaluation, a set of carefully designed prompts is utilized:

- **Prompts for Evaluation:** You are tasked with rating AI-generated summaries of construction research reports based on the given metric. You will be presented with an original research report and AI-generated golden nuggets (key research takeaways) and detailed action items for each golden nugget pulled out from the original research report as input. In the input, the original report is located in the file “original report” while the AI-generated summary is located in the file “summarized contents for the original report”.

Metric:

- Check if the summarized golden nuggets and detail action items are true to the original report.
- The golden nuggets should reflect the key research findings/takeaways majorly discussed in the original report.
- The detailed action items should be a good summary for implementing each golden nugget.
- The summary should be concise.

Evaluation criteria: The task is to judge the extent to which the metric is followed by the summary.

1 - The metric is not followed at all

2 - The metric is followed only to a limited extent

3 - The metric is followed to a good extent

4 - The metric is followed mostly

5 - The metric is followed completely

Return the rating of your evaluation and explain the reasons.

Subject Matter Experts (SMEs) Review: After using the LLM to complete the initial assessment, the refined content is forwarded to SMEs for validation. The SMEs, primarily members of the CII RT-398 team, possess extensive industry experience, ensuring a rigorous evaluation process. Each SME was assigned to validate three Best Practices (BPs) by manually reviewing the original research reports and comparing them against the extracted insights generated by the proposed framework. The validation focused on four key aspects: (1) whether the extracted GNs accurately represent the most critical information from the report, (2) whether the summarized DAIs maintain accuracy and fidelity, (3) whether the GNs are assigned to the appropriate project lifecycle phases (4) whether all link, including research reports and tool links, remain valid. The authors systematically collected SME feedback and incorporated necessary refinements through manual revision, ensuring the final content meets the highest quality and reliability standards. The SME validation process involved multiple rounds of both virtual and in-person meetings. Additionally, students from a major public university in the U.S. who were enrolled in the CII BP course contributed to the validation of BP content through weekly homework assignments.

BP Primer Questionnaire Survey: The following survey template is used for each BP validation by sending to students and SMEs:

- General Introduction for each BP: This survey aims to validate the Safety portion of the CII Best Practice (BP) Primer Tool that is currently under development. We would like you to evaluate the Safety portion of the BP tool based on the following criteria: (1) The accuracy and comprehensiveness of captured contents, and (2) The utility of the tool. Before you complete the survey, you will need to become familiar with the tool by watching this video, and get a general sense of the tool itself, here is the [LINK](#) to the tool. There are 10 reports related to safety in the BP tool. Each report has (1) an overall summary of each research study, (2) key insights (golden nuggets) extracted from the research, and (3) detailed action items corresponding to each golden nugget.
- Questions for each report (Each report has the same two questions):
 - The BP tool effectively captures all relevant content (overall summary, golden nuggets, and detailed action items) related to “Making Zero Accidents a Reality (RT-160)”.
 - Strongly disagree
 - Somewhat disagree
 - Neither disagree nor agree
 - Somewhat agree
 - Strongly agree

- Considering the following: if
 - (1) any golden nuggets are missing;
 - (2) any golden nuggets are not assigned to the appropriate phases;
 - (3) any detailed action items are missing;
 - (4) any detailed actions are not correct; for both owner's and contractor's spreadsheet.

List all the suggestions you have to improve the content of this research in a few bullet points.

- The following questions are related to the utility of the BP Tool.
 - The current usability of BP Tool can help you find useful information. Usability refers to navigation, clear instructions, logical layout, and overall functionality.
 - Strongly disagree
 - Somewhat disagree
 - Neither disagree nor agree
 - Somewhat agree
 - Strongly agree
 - What suggestions do you have to improve the overall BP tool usability?
 - The BP Tool is very useful for the project management.
 - Strongly disagree
 - Somewhat disagree
 - Neither disagree nor agree
 - Somewhat agree
 - Strongly agree
 - Any additional suggestions to improve the BP Tool?

Appendix B: Complexity Survey

A. Background Information

1. What type of company do you work for? (Owner, Contractor, Service Provider, etc.)
2. What is YOUR title in the company?
3. How many years of professional experience do you have in your field?

B. Comparing RT 305 tool with new complexity tool

1. Have you previously used the project complexity assessment and management tool developed under RT-305?

Yes / No

Mentally visualize a project that you have had recent experience with. Assume that you need to assess the complexity of the project and choose appropriate complexity management strategies. Please evaluate the project using both the RT-305 & RT-398 tools.

RT-305 Tool

RT-398 Tool

2. Which tool was easier to use for assessing project complexity?

RT-398 tool / RT-305 tool

Please offer clarification on why you found the selected tool more easier to use compared to the other option.

3. Which tool offers a more streamlined approach to assess project complexity and identify relevant management strategies?

RT-398 tool / RT-305 tool

Please offer clarification on why you found the selected tool more streamlined to use:

C. Overall Evaluation of the RT-398 Tool

Rate your agreement with the following statements about the new RT-398 Complexity Assessment Tool:

1. The tool effectively aids in assessing project complexity.
 - Strongly disagree
 - Somewhat disagree
 - Neither disagree nor agree
 - Somewhat agree
 - Strongly agree

2. The tool provides useful management strategies for project complexities.
 - Strongly disagree
 - Somewhat disagree
 - Neither disagree nor agree
 - Somewhat agree
 - Strongly agree

3. When available, I intend to use this tool for managing project complexities in practice.
 - Strongly disagree
 - Somewhat disagree
 - Neither disagree nor agree
 - Somewhat agree
 - Strongly agree

4. The tool comprehensively captures all relevant attributes and sub-attributes necessary to assess project complexity.
 - Strongly disagree
 - Somewhat disagree
 - Neither disagree nor agree
 - Somewhat agree
 - Strongly agree

5. How would you rate the following approaches in terms of effectiveness and ease of use? Please assign a number from 1 to 4 for each approach, where 1 is the best and 4 is the least preferred.

- General Assessment of Project Complexity
- General Assessment of Project Complexity (Condensed)
- Project Complexity Assessment by Phase
- Project Complexity Assessment per Complexity Area

Please provide your comments:

D. Feedback for Improvement

What improvements would you suggest for the complexity assessment tool RT-398?

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