ABSTRACT

ALBALOUL, ROYA. Development of Project Complexity Assessment and Management Tool for Capital Facility Projects. (Under the direction of Dr. Edward Jaselskis and Dr. Alex Albert)

This thesis explores the development and validation of the Project Complexity Assessment and Management (PCAM) 2.0 tool, designed to enhance the original PCAM tool developed by CII's Research Team 305. The upgraded tool aims to improve usability and accessibility for managing complexities in capital facility projects. By integrating cognitive psychology principles, PCAM 2.0 tool simplifies the complexity assessment process and offers straightforward mitigation strategies, significantly enhancing project outcomes and user satisfaction. Validation in real-world settings has indicated the tool's effectiveness, emphasizing its practicality and relevance in the field. The research highlights the tool's contribution to better project planning and risk management, enabling project managers to proactively address potential challenges. The feedback from diverse industry stakeholders has suggested that PCAM 2.0 meets the industry's evolving needs, thereby increasing its adoption and impact. The study also suggests future enhancements, including the integration of AI and machine learning to further improve its predictive capabilities. This thesis demonstrates the potential of PCAM 2.0 as a critical resource in project management, proposing a robust model for ongoing development in complexity management tools across the construction industry.

Development of Project Complexity Assessment and Management Tool for Capital Facility Projects

by
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DEDICATION

This work is lovingly dedicated to those who have been my pillars of support. To my late father, whose encouragement to pursue my studies abroad resonated with bravery, even during his illness—Dad, I hope I made you proud. To my late stepdad, who has been nothing less than a father to me, providing love and support every step of the way. To my mother, whose endless support and prayers from afar have been my constant comfort—Mom, I hope to continue making you proud. To my friends and family, whose unwavering support has never dimmed—thank you for everything. And to God, who has always been there, listening and guiding, I am eternally grateful. "Learn to be thankful for what you already have, while you pursue all that you want." – Jim Rohn.

BIOGRAPHY

Roya Bader Albaloul was born and raised in Kuwait, the only daughter among five loving brothers. Her unique position in a lively household instilled in her a sense of adaptability and perseverance from a young age. Roya pursued her undergraduate studies in Civil Engineering at Kuwait University, where she laid the groundwork for her future in engineering.

With a solid foundation in civil engineering, Roya embarked on a career that spans over a decade with the Public Authority for Industry in Kuwait. Her expertise in project planning, project controls, and coordination has been crucial in advancing her career to a senior civil engineer position.

Driven by a desire to deepen her expertise and apply her knowledge more broadly, Roya decided to pursue a master's degree in civil engineering with a focus on Construction Engineering at North Carolina State University.

Outside of her academic and professional life, Roya is an avid scuba diver who enjoys the depths of the ocean. Her long-term career goal is to continue her studies and earn a PhD in Civil Engineering, where she aims to further contribute to her field effectively. Her personal philosophy—to keep faith and believe that everything happens for a reason—guides her through challenges both in personal life and professional endeavors.

As she looks forward to next steps, Roya is eager to tackle new challenges and seize opportunities that will allow her to make a significant impact in her field and beyond.

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My heartfelt appreciation goes to my friends, who have been incredibly supportive in teaching me new technologies and helping me navigate the complexities of academic research. Their patience and willingness to share their knowledge have been crucial to my success.

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CHAPTER 1: INTRODUCTION

Project complexity has evolved from being perceived merely as a challenge to becoming a crucial factor that affects all aspects of project management. Traditionally, project complexity was considered a barrier to project success, but modern perspectives acknowledge its dual role as both a challenge and an opportunity. Multiple factors contribute to project complexity and can influence the project's outcome, making the management of complexity critical to achieving project success. Research suggests that a systematic approach to understanding and managing project complexity can significantly improve project outcomes by addressing various dimensions which are critical to navigating complex projects effectively (Azmat & Siddiqui, 2023).

Complexity in capital facility projects arises from various intertwined factors that influence the execution and outcomes of projects. This complexity is characterized by diverse, interrelated components that must be managed effectively to avoid delays, budget overruns, and failure to meet quality standards. Each construction project presents unique challenges due to its distinct characteristics and the extensive integration required among different project elements (Baccarini, 1996; Geraldi et al., 2011).

Research and case studies highlight that a proactive approach to managing complexity, utilizing strategies like front-end planning and change management, can significantly mitigate the risks associated with project complexities and enhance the likelihood of project success (Safapour et al., 2020). However, as mentioned, the consequences of not effectively managing project complexity are severe. Statistical data reveals that cost overruns in large construction projects frequently exceed 80% of their initial budgets, primarily due to the mismanagement of complexity, thereby affecting not only the immediate stakeholders but also having broader economic implications. These broader implications can ripple through the economy, specifically in public projects by influencing public spending, reducing overall economic productivity, and increasing the financial burden on taxpayers who may ultimately bear the costs of budget overruns (Flyvbjerg, 2014).

For instance, the Boston Big Dig, which was a massive urban infrastructure project initially budgeted at $2.6 billion with a 1998 completion target, escalated dramatically to over $14.6 billion and concluded in 2007. This project's cost overrun reached 461.5%, due largely to poor stakeholder alignment and management, exacerbated by political pressures and administrative changes. These issues led to significant delays and further cost overruns, underscoring the importance of effective stakeholder management in controlling costs and timelines in major projects (Altshuler & Luberoff, 2003; Meigs, J. B. (2007).

Similarly, the Denver International Airport project, which faced an overrun nearly $2 billion above the original $1.7 billion budget, demonstrates how poor coordination among different teams and technology integration can lead to significant project delays and budget overruns. This was largely attributed to the complexities introduced by the malfunctioning automated baggage system (de Neufville, 1994).

Additionally, the Montreal Olympic Stadium, intended to be completed for the 1976 Olympics, faced enormous financial problems with costs escalated from an estimated $124 million to over $1.4 billion which totaled the cost overrun to reach 1029%. The completion of the stadium dragged on for 11 years beyond the games, illustrating the drastic impact of poor project management and resource allocation (Patel, 2013).

The severe consequences of inadequate risk management were highlighted by the Fukushima Daiichi nuclear disaster in 2011. Triggered by a natural catastrophe, the disaster was intensified by poor risk management strategies, with cost implications estimated to exceed $187 billion, showcasing the severe repercussions of failing to appropriately manage risks in complex projects (Tabuchi, 2016).

The critical need for robust project management frameworks that integrate sophisticated planning, stakeholder engagement, coordinated execution, effective resource use, and comprehensive risk assessment is evident. These frameworks are essential for managing complexities across key areas such as technical and system integration, resource constraints, and stakeholder alignment to avoid delays and cost overruns. As the field of project management continues to evolve, integrating these frameworks becomes indispensable, ensuring projects not only meet their intended outcomes but also contribute positively to broader economic and developmental goals. This integrated approach is paramount in ensuring the success and sustainability of large-scale projects in the modern context.

However, since complexity science is still a new topic in general and for construction projects in particular (Wood & Gidado, 2008) (Luo et al., 2017), there is no single definition for the word complexity. In linguistics, Complexity is the state or quality of being complex; intricacy. This refers to something that is intricate or complicated, with many interconnected parts (Collins English Dictionary). In construction, these interconnected parts are the factors and criteria that impact the level of complexity, such as stakeholders, project objectives, technology, and many others. While multiple researchers investigated complexity assessment, very few have connected the research with the new world of technology to provide a tool for the construction industry to assess project complexity and provide management strategies to reduce the negative impact of these complexities.

Similarly, defining project complexity requires agreement on the various characteristics that contribute to it. Many terms used to describe project complexity can be further categorized to give clearer, more specific meanings. This helps reduce ambiguity and redundancy, which often add to communication difficulties in complex projects. For instance, vague questions often lead to vague answers, complicating project progress. In this research, the aim is to use more precise language in everyday conversations to better characterize projects in terms of construction complexity (Lafhaj et al., 2024; Albtoush, Rahman & Al-Momani, 2022).

In this thesis, the terminology reflects recent publications on project complexity, including terms like attributes, elements, components, and factors, adhering to established definitions (Remington & Pollack, 2007; Crawford et al., 2005). **Attributes** are inherent properties defining a project's complexity, such as size, scope, technological novelty, and stakeholder diversity. These attributes are often comparable to **Factors**, which are variables or conditions like regulatory demands, technological challenges and stakeholder involvement that influence complexity (Williams, 1999; Baccarini, 1996).

Elements are the fundamental units of a project, encompassing tasks, activities, milestones and deliverables, which collectively form the project structure (Maylor et al., 2013; PMBOK® Guide, 2021). **Components**, on the other hand, are larger sub-systems within the project, such as phases or departments, that require coordinated management to ensure project success (Gidado, 1996; Turner & Cochrane, 1993). These components integrate multiple elements, contributing significantly to overall project complexity and execution.

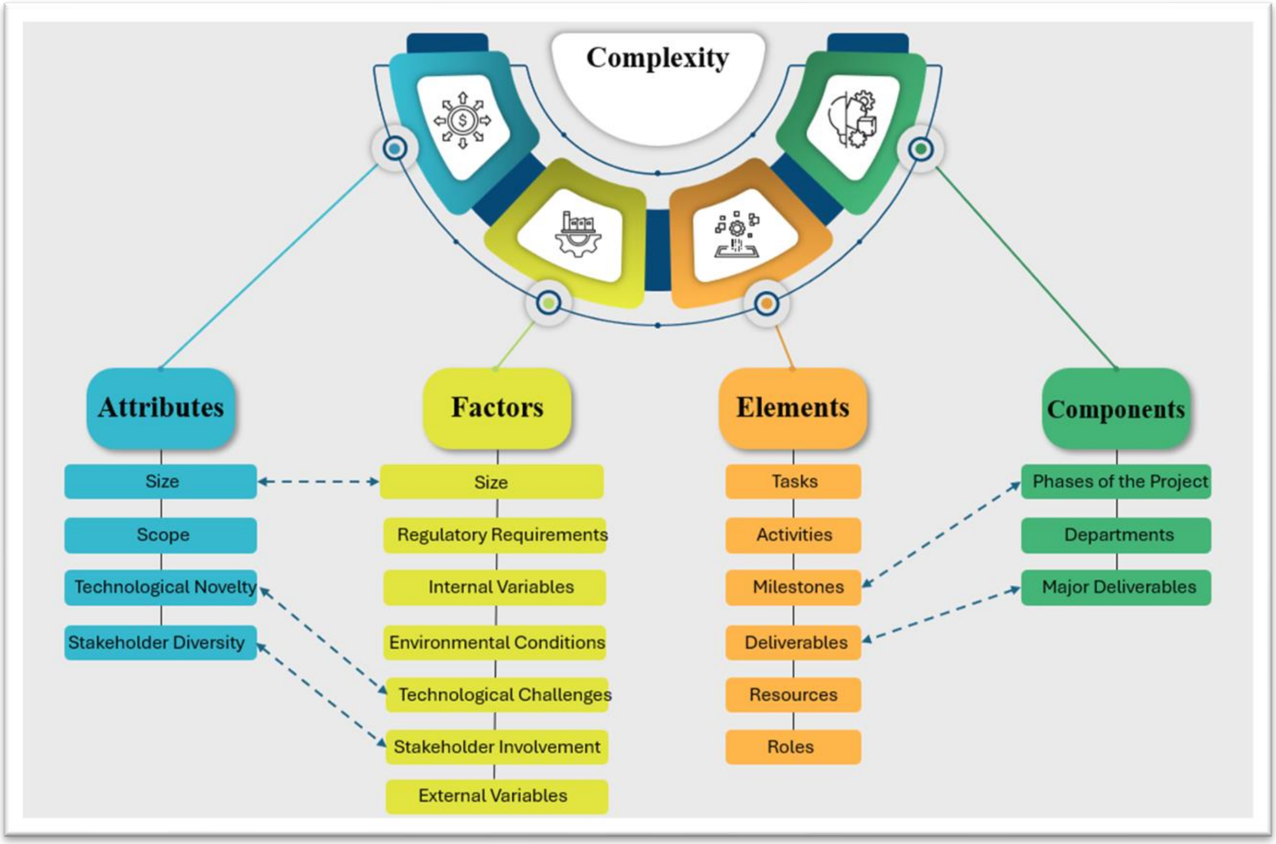


Figure 1.1 *Understanding Complexity Dimensions*

By distinguishing between these terms as shown in Figure 1.1, project managers can gain a more nuanced understanding of what contributes to project complexity and how to address it effectively. By understanding the distinctions between attributes, factors, elements, and components, project managers can better analyze and manage the complexity inherent in their projects, leading to more effective planning and execution. Despite these definitions, there is some discrepancy about which categories stakeholders and stakeholder interactions align with completely. Nonetheless, stakeholder-related issues oftentimes spread across multiple definitions and must be considered for project success; henceforth, all project management aspects benefit from exceptional communication to better connect all stakeholders to the project outcomes.

The challenge of managing project complexity effectively is crucial in the construction industry, especially as projects become more intricate and their environments more dynamic. The Construction Industry Institute (CII) has developed a tool, as part of Research Team 305's efforts, that assesses and proposes management strategies for project complexities. This tool is designed to prevent complexities from escalating into negative risks that could impede project progress.

This research aims to provide a user-friendly complexity assessment tool that would help project managers from the early stages of project inception through to completion. The Introduction is structured to first present the thesis statement which highlights the limitations of existing complexity tools. These limitations underscore the need for a more user-friendly tool to better assess and manage project complexity. The research objectives are then outlined, focusing on the aim to refine and enhance the usability of the complexity assessment tool, making it more accessible and practical for industry professionals. Finally, the significance of this research is discussed, emphasizing the implications and potential benefits of the enhanced tool, which include improved project outcomes, increased efficiency, and more effective complexity management strategies in the construction industry.

1.1 Thesis Statement

The Construction Industry Institute's (CII) Project Complexity Assessment and Management (PCAM) tool, developed by Research Team 305 (RT-305), holds significant potential for enhancing project management. However, its widespread adoption has been somewhat limited due to challenges in navigation and user-friendliness. Similar tools, such as the Interface Complexity Assessment Tool (ICAT) and the Complexity Assessment Tool (CAT), have also been recognized, but the Project Complexity Assessment and Management (PCAM) tool stands out as the most comprehensive, incorporating both complexity criteria and mitigation strategies. Despite this, the PCAM tool's complexity has also restricted its usability. This research is focused on refining the PCAM tool to make it more user-friendly. By simplifying the assessment process and integrating direct guidance, the revised tool aims to encourage wider adoption among project managers and improve project outcomes across the industry.

In recent years, significant efforts were undertaken under RT-398 phase I to develop a fit-for-purpose handbook for the Upstream, Midstream, and Mining (UMM) sector, incorporating many attributes initially identified in previous research. This handbook was designed to address the specific complexities within the UMM sector, establishing a robust foundation for effective complexity management in these projects. However, as the UMM sector has since been dissolved, the focus of RT-398 has shifted in phase II to cover Capital Facility Projects which are large-scale initiatives that often involve multiple stakeholders, intricate technologies, and complex regulatory frameworks more broadly. To achieve broader applicability and build on the solid foundation laid in phase I, it became essential to integrate the comprehensive findings from RT-305. The research conducted by RT-305 offered a detailed identification of key attributes and sub-attributes of complexity, along with effective mitigation strategies. These insights are now being leveraged in RT-398 phase II to develop a more user-friendly tool that can serve a wide range of projects, ensuring that the methodologies initially developed for the UMM sector can now be effectively applied to Capital Facility Projects across the industry (Odhiambo, 2023).

1.2 Research Objectives

The primary aim of this study is to refine and enhance the user-friendliness of the RT-305 complexity tool (PCAM), developed by CII. To achieve this, the research objectives are focused on evaluating existing complexity assessment tools, identifying specific areas where users encounter difficulties, and developing a streamlined version that maintains analytical depth while being easier to use. This process involves a comprehensive review and revision of the tool's attributes, followed by validation and feedback analysis to ensure the modifications improve usability and adoption levels. The specific objectives of the study are as follows:

1. Evaluate the existing complexity assessment tools either developed by CII or by other organizations and individuals, understanding their structure, functionality, and areas where users encounter difficulties.
2. Develop a streamlined version of the tools that organize certain attributes, sub-attributes and management strategies in such a way as to reduce complexity without compromising the depth of analysis.
3. Test the revised tool (Validation Process) with a group of users to gather feedback on its efficacy and ease of use, ensuring the modifications enhance user experience and applicability.
4. Analyze the feedback to determine how the revised tool impacts the management of project complexities and the ability of project teams to mitigate associated risks.

1.3 Significance of Research

This thesis contributes to the body of knowledge in project management by providing a practical, user-friendly tool for assessing and managing project complexity. The anticipated outcome is a tool that not only simplifies complexity assessment but also enhances the strategic management of projects, thereby fostering more successful project completions across various sectors within the construction industry. The significance of this study is underscored by several key benefits:

1. **Enhanced Decision Making**: By assessing complexities more accurately, the tool can provide deeper insights into potential challenges and risks. This empowers project managers and decision-makers to make more informed choices, potentially reducing the likelihood of project delays and cost overruns.
2. **Improved Project Planning**: With a better understanding of the complexities involved, project planners can develop more effective strategies and allocate resources more efficiently. This leads to smoother project execution and higher chances of meeting project deadlines and budgets.
3. **Increased Adaptability**: By including mitigation strategies, the tool not only identifies risks but also suggests ways to manage them. This proactive approach makes projects more adaptable to changes and unforeseen issues, enhancing overall project flexibility.
4. **Cost Efficiency**: Effective complexity management can lead to cost savings. By anticipating and mitigating complexities early on, the user can avoid expensive consequences and resource wastage, optimizing budget allocation.
5. **Stakeholder Confidence**: A clear method for assessing project complexities increases trust from everyone involved, including investors and clients, by demonstrating that potential problems are being handled properly.
6. **Lessons Learned**: The tool helps organizations learn from each project, improving their methods and strategies over time, which benefits future projects.

By addressing these aspects, this study aims to create a valuable resource that enhances the ability of construction industry professionals to manage project complexities effectively, leading to improved project outcomes and overall industry advancement.

CHAPTER 2: LITERATURE REVIEW

The purpose of this literature review is to provide a comprehensive background for the study focused on reviewing and refining existing tools that assess and manage project complexity. This chapter offers insights into project complexity management, identifies gaps in the current methodologies, and supports the development of a refined, user-friendly complexity assessment tool that incorporates actionable mitigation strategies.

The literature review begins by introducing the concept of project complexity and progresses to an examination of various existing complexity assessment tools. Special attention is given to the Project Complexity Assessment and Management (PCAM) Tool developed by CII, as well as other notable tools such as the Interface Complexity Assessment Tool (ICAT) and the Complexity Assessment Tool (CAT). These tools are critically analyzed to highlight their strengths, limitations, and areas requiring improvement.

A key finding from the review is the recognition of user-unfriendliness and the lack of integration with actionable mitigation strategies as significant limitations in existing tools. These issues often hinder their practical application and effectiveness in real-world settings. By identifying these shortcomings, the review informs the design of a new tool that aims to be more intuitive and directly applicable to project management practices.

Furthermore, the review underscores the importance of incorporating proven best practices from various studies into the new tool. This approach ensures that the tool is grounded in established research while addressing the critical need for tools that not only evaluate but also actively manage project complexity. The proposed tool will feature dual functionality, making it more useful for project managers by providing both assessment metrics and mitigation strategies.

The chapter concludes by synthesizing the literature, connecting key findings to the objectives of this study. This sets the stage for developing and validating an enhanced tool. The results of this review provide a solid theoretical and practical foundation for the new tool, enhancing the management of project complexity in the construction industry.

2.1 Difference between complexity, risk, and uncertainty

Complexity, risk, and uncertainty are key concepts in project management, each distinct yet interrelated, and together they influence how projects are planned and managed. Project **Complexity** is often defined as the state of having many interconnected elements that are difficult to understand or manage, emphasizing the intricate and interrelated nature of project components (Vidal & Marle, 2008). It involves factors such as multiple stakeholders, technological innovation, legal requirements, and complex organizational structures, all of which complicate project planning and execution (Lizarralde et al., 2012). This complexity increases the susceptibility to risks, potentially leading to cost overruns and schedule delays.

In addition, complexity in projects results from the numerous interconnected elements and their interactions, creating challenging and dynamic environments for project managers (Geraldi et al., 2011). These conditions can produce unpredictable outcomes, requiring advanced strategies to manage dependencies and coordinate different project aspects effectively. Proper management of complexity is critical for controlling the project lifecycle and achieving efficient results (Maylor et al., 2008).

Risk involves the probability of occurrence of events that could positively or negatively impact project objectives. Characterized by the likelihood and magnitude of potential consequences, risk necessitates the implementation of mitigation or management strategies to reduce potential adverse effects on a project. The Project Management Institute (PMI) defines risk as an uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives (PMBOK, 2021).

Uncertainty refers to the lack of understanding and awareness of issues, events, paths to follow, or solutions to pursue. Uncertainty deals with the probabilities of alternative actions, reactions, and outcomes. Uncertainty includes unknown unknowns and black swans, which are emerging factors that are completely outside of existing knowledge or experience (PMBOK, 2021). Ward and Chapman (2003) define uncertainty as the state of having limited knowledge, making it difficult to describe the exact current state or future outcomes, or to assign probabilities to future events.

Understanding the distinctions and interactions among complexity, risk, and uncertainty is crucial for effective project management, affecting decision-making processes, planning, and execution strategies. Each concept plays a significant role in how projects are approached, demanding specific management techniques to ensure success.

2.2 Types of Complexity

As seen in Figure 2.1, various types of complexity are identified in the literature, including structural, social, and contextual complexities, each contributing to the intricate nature of project management.

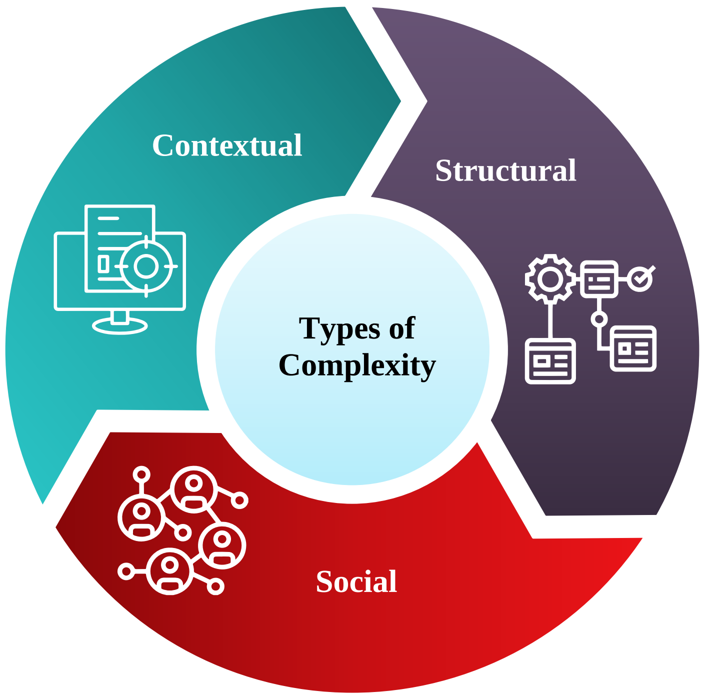


Figure 2.1 *Complexity types*

Structural complexity relates to the size of the project, the number of systems involved, and their interdependencies, often influenced by the project's scope, scale, and technological solutions (Williams, 1999). This complexity not only involves the sheer number of elements and their relationships but also extends to technological complexity, which addresses the innovation and newness of technologies used in the project (Baccarini, 1996).

Social complexity deals with the human aspects, such as coordination among diverse teams, communication challenges, and stakeholder management. It is heightened by varying objectives, cultures, and interactions among project participants, making governance and relationship management crucial (Cooke-Davies, 2002; Baccarini, 1996).

Contextual complexity, often referred to as uncertainty, encompasses the unknowns that complicate project planning and execution. This type includes both external factors like regulatory changes and internal factors such as unforeseen technical challenges (Atkinson et al., 2006). Additionally, project-specific complexities like regulatory, social, and economic conditions also play a significant role (Siddiqui & Azmat, 2023).

These dimensions collectively underline the importance of comprehensive management approaches to address the challenges presented by project complexity.

2.3 Navigating Complexity: Insights from PMBOK Guide

According to the PMBOK Guide, complexity is characterized as an inherent feature of a project or its environment that complicates management efforts due to these intricate elements. It identifies several sources that contribute to complexity. **Human behavior**, encompassing the conduct, attitudes, and experiences of individuals involved in the project, can introduce subjectivity and conflict with project goals. **System behavior** refers to the dynamic interdependencies within the project, which may lead to risks, unforeseen issues, and unclear cause-and-effect relationships. Additionally**, uncertainty and ambiguity** stem from a lack of clarity and understanding about the project's direction, choices available, and potential outcomes. **Technological innovation** can also add complexity by disrupting established processes and introducing new uncertainties in project execution.

To navigate this complexity, it is recommended that project teams remain vigilant in identifying complex elements and adapt their management approaches accordingly. This includes continually evaluating and navigating through complexity by employing proactive planning and adaptive strategies. Emphasizing systems thinking, leveraging past project experiences, experimenting, and continuous learning are essential for enhancing the project team's ability to manage and mitigate the impacts of complexity. By being proactive and flexible, project teams can better manage complexity and ensure successful project delivery (PMBOK, 2021).

2.4 Complexity Assessment's Impact on Project Execution

Complexity assessment is essential throughout both the planning and execution phases of capital facility projects, enabling project managers to devise accurate plans and manage potential challenges effectively. Vidal and Marle (2008) emphasize that understanding the interdependencies among project elements through complexity assessment is crucial for meticulous planning and resource allocation. During the planning phase, this assessment is instrumental in pinpointing critical areas needing special attention, such as the project's scope, technological requirements, stakeholder involvement, and regulatory constraints. This thorough evaluation allows for the development of comprehensive project plans that preemptively address potential risks and uncertainties, as noted by Williams (1999). For example, a deep understanding of technological complexity aids in the selection and integration of suitable technologies into the project.

In the execution phase, complexity assessment continues to play a vital role by keeping project managers informed of ongoing challenges, allowing for the adaptation of strategies as needed. Gidado (1996) points out that this phase benefits from continuous monitoring and evaluation of project progress, enabling timely corrective actions that help maintain control and efficiently achieve project goals.

Effective management of project complexity is directly linked to the success of projects, which are less likely to suffer from cost overruns, delays, and quality issues when complexity is properly managed. Studies have consistently shown that adequate complexity management enhances project performance and increases success rates. One significant advantage of effective complexity management is improved risk mitigation. By identifying and addressing various complexity dimensions, project managers can craft targeted risk management strategies that diminish the likelihood of adverse events, according to Atkinson, Crawford, and Ward (2006). Moreover, effective complexity management improves stakeholder management by enhancing communication and coordination strategies, as stated by Cooke-Davies (2002), leading to greater stakeholder satisfaction and support, which are essential for project success.

As complexity impacts project costs, duration, and risk management significantly. Projects with greater structural and technological complexity generally incur higher costs due to the increased management efforts required, as found by Gidado (1996). Additionally, such complexities can lead to unexpected expenses related to compliance and adaptation to regulatory and environmental challenges. Complexity can extend project durations as well, particularly in scenarios with high interconnectivity and interdependencies among project elements, which often result in delays due to coordination challenges and necessary rework, highlighted by Vidal and Marle (2008). Projects with extensive stakeholder involvement and technological demands are especially susceptible to such delays. Effective risk management is crucial for handling these complexities, with complexity assessment playing a key role in early identification and strategy development for managing risks like scope changes, technical challenges, and stakeholder conflicts. Understanding regulatory and environmental factors, for instance, helps in anticipating potential legal and environmental issues, facilitating their effective management and mitigation.

2.5 Tools and Approaches for Assessing Project Complexity

Assessing project complexity is a vital part of project management, particularly within the construction industry. Various tools and methods have been developed over the years to evaluate the complexities inherent in projects. This section reviews traditional tools and approaches used to assess project complexity, highlighting their methodologies, strengths, and limitations.

2.5.1 Project Complexity Assessment and Management (PCAM) Tool

Developed by Research Team 305 under the supervision of the CII, this tool stands out as a comprehensive instrument for assessing project complexity. It incorporates 37 indicators that span a wide array of factors including stakeholder management, governance, legal requirements, and fiscal planning. This tool is designed to help project teams gauge the level of complexity and offers actionable strategies for effective management (Construction Industry Institute, 2018). While it provides extensive coverage of complexity attributes and sub-attributes, the PCAM Tool also presents certain challenges; it can be complex as seen in Figure 2.2 and time-consuming to implement and often requires considerable expertise to interpret and apply effectively.

IR 305-2, Project Complexity Assessment and Management Tool

Complexity Measurement Matrix

Complexity Indicator	Complexity Measure	Complexity Score				Note/Comment
		1	2	3		
Stakeholder Management, Governance, Fiscal Planning, and Quality						
CI-1_Assess the anticipated influence of this project on the organization's overall success (e.g., profitability, growth, future industry position, public visibility, and internal strategic alignment).	Limited Contributor	1	2	3	N/A	**Comments for CI-1**
	Moderate Contributor	4	5	6		
	Substantial Contributor	7	8	9		
CI-2_Assess the anticipated impact of required approvals from external stakeholders on the original project execution plan. **(Stakeholder Management)**	Low Impact	1	2	3	N/A	**Comments for CI-2**
	Moderate Impact	4	5	6		
	Substantial Impact	7	8	9		
CI-3_Assess the anticipated impact of required inspection by external (regulatory) agencies/entities on the original project execution plan. **(Stakeholder Management)**	Local Entities (Low Impact)	1	2	3	N/A	**Comments for CI-3**
	State Entities (Moderate Impact)	4	5	6		
	National Entities (Substantial Impact)	7	8	9		
CI-4_Identify the total number of joint-venture partners on this project. **(Governance)**	Low Number of Partners	0	1	2	N/A	**Comments for CI-4**
	Medium Number of Partners	3	4	5		
	High Number of Partners	6	7	8 or more		
CI-5_Anticipate how many executive oversight entities above the project management team will have decision-making authority on the project execution plan. **(Governance)**	Low Number of Entities	1	2	3	N/A	**Comments for CI-5**
	Medium Number of Entities	4	5	6		
	High Number of Entities	7	8	9 or more		
CI-6_Anticipate the number of times on this project that a change order (CO) will need to go above the Project Manager for approval. **(Governance)**	Significant Cost Threshold of CO	0	1	2	N/A	**Comments for CI-6**
	Moderate Cost Threshold of CO	3	4 or 5	6 or 7		
	Minimal Cost Threshold of CO	8	9	10 or more		
CI-7_Identify the number of funding phases (gates) from concept to project completion. **(Fiscal Planning)**	Low Number of Phases	1	2	3	N/A	**Comments for CI-7**
	Medium Number of Phases	3	4	5		
	High Number of Phases	6	7	More than 7		
CI-8_Assess any specific delays or difficulties in securing project funding. **(Fiscal Planning)**	Short Delays	1 Week or Less	2 to 4 Weeks	5 to 7 Weeks	N/A	**Comments for CI-8**
	Medium Delays	8 to 10 Weeks	11 to 13 Weeks	14 to 16 Weeks		
	Long Delays	17 to 19 Weeks	20 to 22 Weeks	23 Weeks or More		
CI-9_Assess any quality issues with bulk materials during project execution. **(Quality)**	Low Number of Quality Issues	1	2	3	N/A	**Comments for CI-9**
	Moderate Number of Quality Issues	4	5	6		
	Substantial Number of Quality Issues	7	8	9		

Figure 2.2 *Original PCAM RT-305 Tool*

2.5.2 Project Complexity and Risk Assessment (PCRA) Tool

PCRA Tool, developed by the Government of Canada, offers a detailed assessment of project complexity and risk through a comprehensive questionnaire that encompasses 64 questions across various dimensions under 7 sections (Table 2.1) including project characteristics, strategic management, procurement, and project management practices. Designed to identify potential risks and complexities early in the project lifecycle, this tool allows for a thorough evaluation across multiple complexity and risk factors (Treasury Board of Canada Secretariat, 2015). However, the tool does have its limitations; it can be resource-intensive to complete, may require extensive training for effective use, and does not provide specific mitigation plans for each identified complexity factor. Instead, it highlights high-risk areas, enabling project managers to focus their attention and develop their own mitigation strategies based on the assessment results. The output from the tool is a score for each section, defined in Table 2.2, providing a quantifiable measure of the project's risk and complexity level.

Table 2.1 *Project Complexity and Risk Assessment (PCRA) Tool - Sections*

Section	Description
Project Characteristics (18 Questions)	This category is designed to build a profile of a given project with respect to key attributes, including funding, budget, size and number of resources, duration, scope, technology scope, stakeholders, dependencies, and external considerations.
Strategic Management Risks (6 Questions)	This category assesses a project's alignment with the organization's investment plan: • Is the project well-positioned to achieve the goals and objectives of the plan? • Is the project a potential risk to the plan?
Procurement Risks (9 Questions)	This category assesses the extent to which procurement activities present potential risks to the project.
Human Resource Risks (5 Questions)	This category assesses whether the project team has the right skill sets in place, with the appropriate roles and responsibilities.
Business Risks (5 Questions)	This category assesses the extent to which the project affects the organization operationally and from a legislative perspective.
Project Management Integration Risks (6 Questions)	This category assesses whether the project demonstrates implementation of key project management control measures and deliverables. This assessment includes addressing the state of the project management plan, project management and control disciplines, and information management processes.
Project Requirements Risks (15 Questions)	This category assesses, by considering the number, type, and degree of certainty of the requirements, the extent to which the specific requirements of the project add risk and complexity.

Table 2.2 Project Complexity and Risk Assessment (PCRA) Tool - Levels

Complexity and Risk Level	Definition	Score
1. Sustaining	Project has low risk and complexity. The project outcome affects only a specific service or at most a specific program, and risk mitigations for general project risks are in place. The project does not consume a significant percentage of departmental or agency resources.	less than 45
2. Tactical	A project rated at this level affects multiple services within a program and may involve more significant procurement activities. It may involve some information management or information technology (IM/IT) or engineering activities. The project risk profile may indicate that some risks could have serious impacts, requiring carefully planned responses. The scope of a tactical project is operational in nature and delivers new capabilities within limits.	45 to 63
3. Evolutionary	As indicated by the name, projects within this level of complexity and risk introduce change, new capabilities and may have a fairly extensive scope. Disciplined skills are required to successfully manage evolutionary projects. Scope frequently spans programs and may affect one or two other departments or agencies. There may be substantial change to business process, internal staff, external clients, and technology infrastructure. IM/IT components may represent a significant proportion of total project activity.	64 to 82
4. Transformational	At this level, projects require extensive capabilities and may have a dramatic impact on the organization and potentially other organizations. Horizontal (i.e. multi-departmental, multi-agency, or multi-jurisdictional) projects are transformational in nature. Risks associated with these projects often have serious consequences, such as restructuring the organization, change in senior management, and/or loss of public reputation.	83 and over

2.5.3 Interface Complexity Assessment Tool (ICAT)

The Interface Complexity Assessment Tool (ICAT), developed by Research Team 302 under the support of CII, is specifically designed to address the complexities that arise from interactions between various project interfaces. This tool focuses on identifying and managing the interdependencies and interactions among different project elements and stakeholders, aiming to enhance communication and coordination among project teams (Construction Industry Institute, 2014). While the ICAT is effective in handling interface-related complexities, it has its limitations. It may not fully capture complexities related to technological or organizational factors and requires detailed information about project interfaces, which may not always be readily available (Figure 2.3).

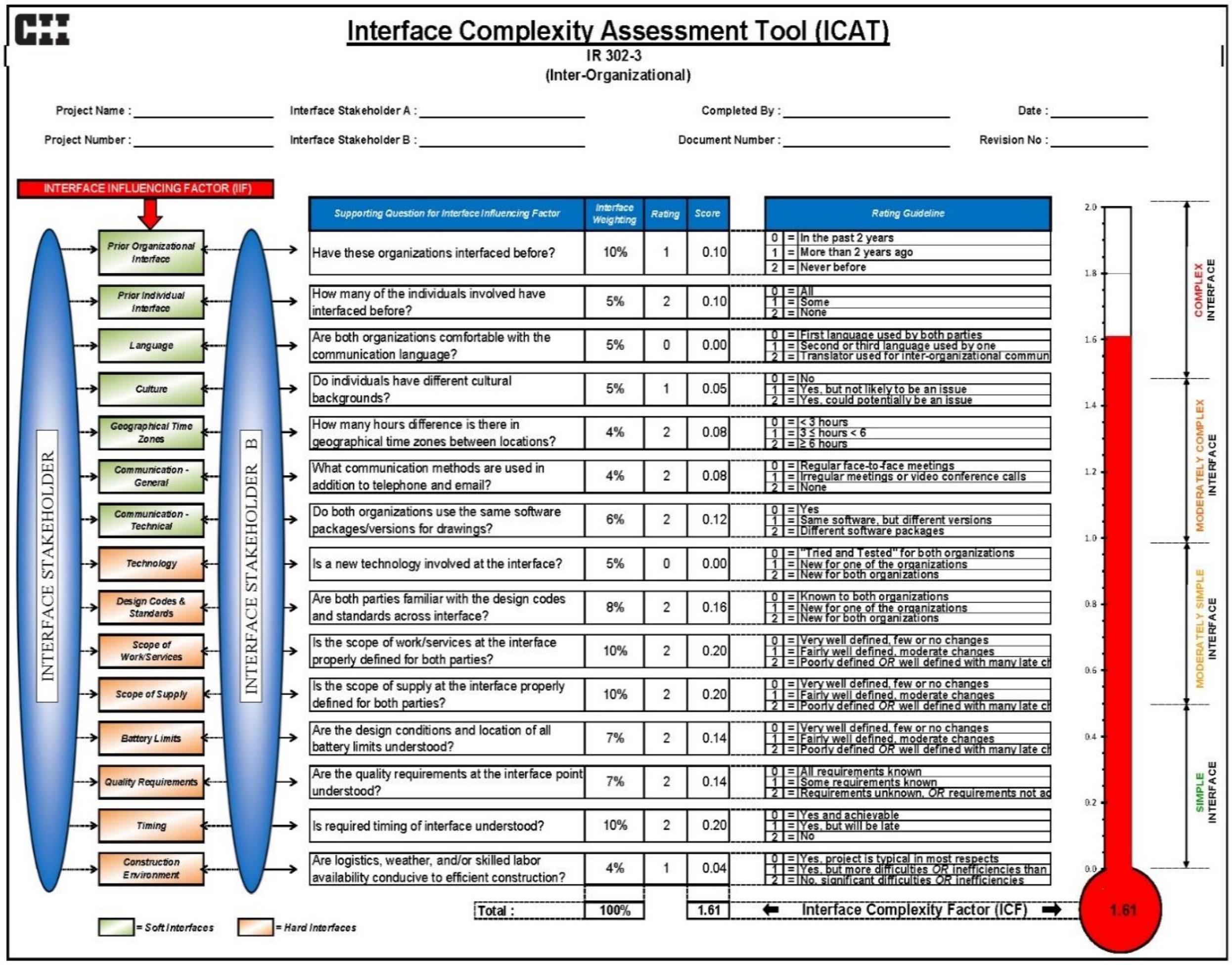


Figure 2.3 Interface Complexity Assessment Tool (ICAT)

2.5.4 Complexity Assessment Tool (CAT)

The Complexity Assessment Tool (CAT), developed by Maylor, Turner and Murray-Webster (2013) is an instrument for assessing project complexity and utilizing a systematic approach to evaluate a variety of factors that contribute to complexity, including project scope, technological novelty, and budget. This questionnaire-based approach to evaluating complexity aids project managers in understanding the overall complexity of their projects. It assesses multiple dimensions of complexity—structural, socio-political, and emergent—offering a comprehensive overview and pinpointing specific areas needing focus. However, CAT does have limitations; most importantly, it does not offer any mitigation strategies to manage the identified complexity factors (Figure 2.4).

The Complexity Assessment Tool (Abbreviated Version)			
Areas of complexity Structural Complexity (1–21) Socio-political Complexity (22–32) Emergent Complexity (defined by expectations for stability)		Do you agree with this statement? (Y/N)	Do you expect this situation to remain stable (i.e., NOT to change)? (Y/N)
Structural Complexity			
1	The vision and benefits for the work can be clearly articulated.		
2	The technology is familiar to us.		
3	The commercial arrangements are familiar to us.		
4	A schedule and resource plan can be well defined.		
5	Existing management tools can support the work.		
6	Sufficient people with the right skills are available.		
7	The work is independent of other projects and business-as-usual operations.		
8	The pace is achievable.		
...	...		
Socio-political Complexity			
22	The work has clear sponsorship consistent with its importance.		
23	Your own senior management supports the work.		
24	Team members are motivated and function well as a team.		
25	The work involves no significant organizational/cultural change.		
26	The external stakeholders (i.e., not immediate team members) are aligned, supportive, and committed to the project and have sufficient time for the work.		
...	...		

Figure 2.4 *The Complexity Assessment Tool (CAT)*

2.5.5 Tools Summary

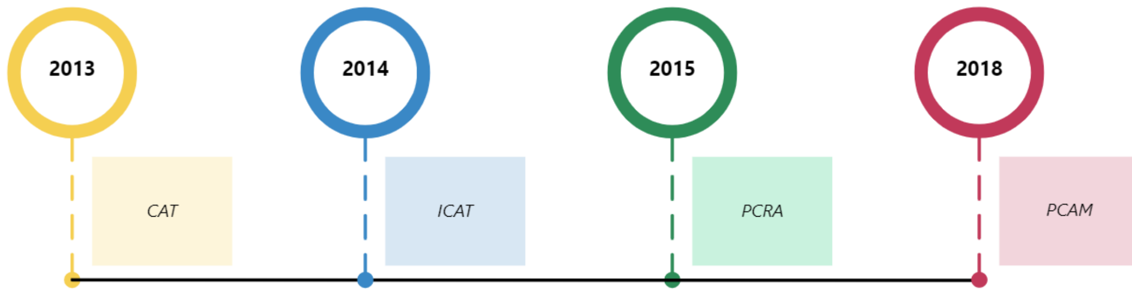


Figure 2.5 *Evolutionary Timeline of Key Complexity Management Tools*

Figure 2.5 illustrates the evolutionary timeline of key complexity management tools, showing the development from CAT in 2013 through to PCAM in 2018. While traditional tools and approaches for assessing project complexity provide valuable insights, they also have limitations that can impact their effectiveness as summarized in Table 2.3. The review of these tools highlights the need for a refined, user-friendly complexity assessment tool that not only evaluates complexity but also provides actionable mitigation strategies. By addressing the limitations of existing tools, the proposed tool aims to enhance the ability of project managers to effectively manage complexity in construction projects.

Table 2.3 Comparative Analysis of Project Complexity Assessment Tools

Tool	Features	Strengths	Limitations
Project Complexity Assessment and Management (PCAM)	- Developed by CII - 37 complexity indicators. - Comprehensive assessment. - Includes scoring mechanism and mitigation strategies.	- Detailed and structured. - Covers various aspects of complexity. - Provides actionable management strategies.	- Complex and time-consuming to use. - Requires significant expertise. - User-unfriendliness limits adoption.
Project Complexity and Risk Assessment Tool (PCRA)	- Developed by the Government of Canada. - A questionnaire-based approach with 64 questions covering various dimensions under 7 sections.	- Comprehensive overview of project complexity. - Helps in early risk identification.	- Time-consuming. - Requires training for effective use. - Does not provide specific mitigation plans.
Interface Complexity Assessment Tool (ICAT)	- Developed by CII - manages complexities arising from interactions among project interfaces.	- Enhances communication and coordination. - Effective for interface-related complexities.	- Limited scope: Does not fully address technological or organizational complexities.
Complexity Assessment Tool (CAT)	- A questionnaire-based approach to evaluating complexity. - Considers multiple factors contributing to project complexity.	- Comprehensive overview of project complexity. - Assesses multiple dimensions: structural, socio-political, emergent.	- Does not provide specific mitigation plans for each identified complexity.

2.6 Advances in Complexity Tools: The Incorporation of AI and Data Analytics

The application of artificial intelligence and machine learning in project management has been widely discussed in academic and professional literature. According to Osei-Kyei et al. (2020), AI technologies can process vast amounts of data to identify trends and patterns that would be impossible for humans to detect manually, or if possible, would take an incomparable amount of time. This capability is particularly useful in complexity assessment, where numerous interrelated factors must be considered.

Machine learning algorithms can analyze historical project data to predict future project complexity and associated risks. For example, supervised learning models can be trained on past project outcomes to forecast potential issues in new projects, allowing for proactive management (Zou et al., 2018). Additionally, data analytics enables the continuous monitoring of project performance, providing real-time feedback that helps in adjusting project plans and strategies dynamically (Bryde et al., 2013).

Data analytics also plays a crucial role in enhancing complexity assessment tools. By leveraging big data techniques, project managers can integrate and analyze data from multiple sources, such as project management software, financial systems, and stakeholder communications. This holistic view allows for a more comprehensive understanding of project complexity and the identification of hidden risks (Bello & Oyedele, 2020).

Several case studies have demonstrated the significant impact that technological innovations can have on complexity assessment in construction projects. One notable example is a case study conducted by Deloitte, where machine learning models were employed to predict risk levels throughout the life cycle of a major infrastructure project. By analyzing historical data from similar projects, these models were able to identify key risk factors, allowing the project team to concentrate their efforts on high-risk areas. This data-driven approach not only enhanced risk management but also led to improved overall project performance (Deloitte, 2019).

Another compelling example is the use of advanced data analytics in the Crossrail project in the UK, which is one of the largest infrastructure projects in Europe. The project team integrated data from various sources, such as design, construction, and operational systems, to create a comprehensive digital model of the project. This model facilitated real-time monitoring and analysis of project progress, enabling more informed decision-making and more efficient management of project complexity. The integration of such advanced analytics tools proved to be instrumental in navigating the intricate challenges posed by a project of this scale (Crossrail, 2018).

The incorporation of AI, machine learning, and data analytics into complexity assessment tools has revolutionized project management in the construction industry. These technologies enable more accurate and dynamic assessment of project complexity, improve risk prediction and management, and enhance overall project performance. As the construction industry continues to embrace technological innovations, the ability to effectively manage complexity will become increasingly critical to project success.

CHAPTER 3: METHODOLOGY

Building on the discussions from previous chapters, this chapter digs deeper into the search for an effective tool. Despite the development of numerous methodologies to address these challenges, finding a tool that accurately assesses complexity and delivers actionable mitigation strategies remains a critical area of ongoing research. Here, we outline the methodology used to develop and refine the Project Complexity Assessment and Management (PCAM 2.0), a tool specifically designed to evaluate project complexity and suggest effective mitigation strategies.

This research aims to build upon the foundation laid by the original PCAM Tool by creating a more accessible and user-friendly model. PCAM 2.0 is designed to not only assess the level of project complexity but also provide tailored mitigation strategies to manage and reduce complexity. The development and validation of this tool involves several key methodological steps, as outlined in this chapter.

The methodology chapter is structured as follows:

1. **Research Design**: This section explains the research approach and design adopted in this study.
2. **Data Collection Methods**: This section details how data was collected to evaluate and refine the complexity assessment tool.
3. **Tool Development**: This section describes the steps taken to develop and enhance the tool, with a focus on improving user-friendliness.
4. **Validation of the Tool**: This section outlines the methods used to validate the tool and ensure its effectiveness in assessing complexity and providing mitigation strategies.

3.1 Research Design

The research design for this study is grounded in **interpretivism**, a research philosophy commonly used in qualitative research. Interpretivism allows for subjective observation of reality, recognizing that reality is unique to each observer. This approach is suitable for this study as it focuses on understanding the nuances and complexities of project management through the perspectives of industry experts. In contrast, positivism represents a fundamentally different research philosophy. Positivism is typically associated with quantitative research and is based on the belief that reality is objective and can be observed and measured independently of the observer. Positivists seek to uncover universal truths or laws by using empirical evidence and statistical analysis to test hypotheses. This approach is often used in studies that aim to establish cause-and-effect relationships and generalize findings across different contexts. Unlike interpretivism, which emphasizes the subjective and context-dependent nature of knowledge, positivism prioritizes objectivity, reliability, and replicability in research findings (Alharahsheh & Pius, 2020).

The research adopts a **deductive** approach, starting with a theoretical framework that outlines the attributes and sub-attributes necessary for creating PCAM 2.0. The deductive method is appropriate as it allows the research to begin with established theories and frameworks, which are then tested and confirmed through practical data. In contrast, an inductive approach works in the opposite direction. Instead of starting with a theory, inductive research begins with observations or data collection. Researchers analyze this data to identify patterns, relationships, or themes, which are then used to develop new theories or frameworks. This approach is more exploratory in nature, allowing researchers to build theories from the ground up based on the data they observe. While deductive research is more structured and aims to test existing theories, inductive research is more flexible and open-ended, making it ideal for discovering new insights in less well-understood areas of study (Pandey, 2019).

This research incorporates both **qualitative** and **quantitative** research methods, offering a balanced approach suitable for the comprehensive exploration of project complexity. Qualitative methods are employed to derive rich, detailed insights from industry experts about the nuances of project complexity. This approach is particularly valuable for gaining a deep, contextual understanding of the intricacies involved and refining the tool based on expert feedback. Simultaneously, the research leverages quantitative methods, including the use of surveys that feature Likert scales for structured, numerical data collection alongside open-ended questions that allow for qualitative input. This combination facilitates the statistical analysis of data to identify patterns, relationships, or trends while also capturing nuanced perspectives and detailed responses that enhance the overall depth of the study. This mixed-methods approach allows for both the testing of hypotheses and the quantification of relationships across large groups while also providing rich, detailed insights. By combining qualitative and quantitative research, this method offers a well-rounded view of the research problem, enhancing the analysis and management of project complexity (Gelo et al., 2008).

3.2 Data Collection Methods

3.2.1 Research Strategy

The research strategy selected for this study is **action research**. Action research is particularly suitable for this study because it involves an iterative process of actively collaborating with industry members to develop and refine PCAM 2.0. This strategy allows for continuous feedback and adjustments, ensuring the tool is both practical and aligned with the users' needs.

The choice of action research over other strategies, such as experimental, case study, ethnography, grounded theory, and phenomenology, is driven by the need for direct involvement with industry practitioners and the ongoing development and refinement of the tool. Action research is focused on practical problem-solving and improving processes, which aligns well with the objectives of this study. In contrast, strategies like experimental research aim to test hypotheses under controlled conditions, while ethnography and phenomenology are more focused on exploring cultural and experiential aspects, which are not the primary focus of this study. Grounded theory is more suited for generating new theories, while a case study would be more appropriate for an in-depth analysis of a single instance. The collaborative, iterative nature of action research made it the best fit for this study's goals (Johannesson & Perjons, 2021).

3.2.2 Time Horizon

The time horizon for this research is **cross-sectional**. This approach involves collecting data at a single point in time, which is effective for this study due to time constraints. Cross-sectional studies are suitable when the research objective is to capture a snapshot of a particular phenomenon or set of conditions at one moment in time. This approach contrasts with a **longitudinal** time horizon, where data is collected over an extended period to observe changes and developments. Longitudinal studies are valuable for tracking changes over time, but in this study, collecting data at multiple points would not significantly affect the outcomes. Therefore, a cross-sectional approach was chosen as it allows for the efficient gathering of necessary data within the limited timeframe available for the research (Johannesson & Perjons, 2021).

3.2.3 Sampling Strategy

The research also employed a **non-probability** sampling strategy, specifically **convenience sampling**. This method was chosen because it allowed the research team to leverage the expertise of industry members who were readily available and willing to participate in the study. Non-probability sampling, unlike probability sampling, does not involve random selection and is often used when a specific population is readily accessible and where statistical generalization to a larger population is not the primary objective. In this case, convenience sampling was appropriate because the focus was on obtaining detailed, expert feedback from a specific group of industry professionals involved in the development and refinement of the tool. This approach ensured that the most relevant and knowledgeable participants were included, which was crucial for the success of the action research strategy (Johannesson & Perjons, 2021).

3.2.4 Summary of research design and Data collection Methods

Table 3.1 summarizes the research design and data collection methods used in Chapter 3, emphasizing an interpretivist approach, a mix of qualitative and quantitative methods, and a deductive reasoning process. It details the use of action research as the strategy, a cross-sectional time horizon, and convenience sampling under a non-probability framework, highlighting key decisions in the study’s design and data collection.

Table 3.1 Research Design and Data Collection Methods

	Available options		Adopted Option
Research Design	• Interpretivism	• positivism	Interpretivism
	• Deductive	• inductive	Deductive
	• Qualitative	• Quantitative	Mixed-method
Research Strategy	• action research • experimental • case study	• ethnography • grounded theory • phenomenology	action research
Time Horizon	• cross-sectional	• longitudinal	cross-sectional
Sampling Strategy	• Probability	• Non-Probability	Non-Probability
Non-Probability Sampling Options	• Convenience • Judgmental	• Snowball • Quota	Convenience

3.3 Tool Development

The development of PCAM 2.0 involved several key steps aimed at enhancing its effectiveness and user-friendliness. Initially, a comprehensive literature review was conducted to explore existing literature and tools, including the CII's RT-305. This review established a solid foundation for the tool's attributes, sub-attributes, and mitigation strategies, ensuring a robust theoretical foundation.

Following the literature review, a collaboration with industry experts from the CII was initiated. Forming a team composed of these experts was crucial as their practical insights and feedback played an important role in shaping the tool. This collaborative approach allowed for the integration of real-world experiences and preferences, making the tool more relevant and applicable to industry needs.

With the foundation set and a team in place, the development process of PCAM 2.0 became highly iterative. The tool was continuously refined based on the feedback from the industry experts. Each iteration focused on enhancing the tool's functionality and usability, ensuring that each version was an improvement over the last.

A significant emphasis was also placed on user-friendliness. Special attention was given to making the tool intuitive and easy to use to ensure that it could be readily adopted by practitioners in the field. This focus on user experience aimed to reduce barriers to adoption, making it easier for project managers and teams to integrate PCAM 2.0 into their workflows.

3.4 Validation of the Tool

A comprehensive approach was adopted to validate this tool. First, interviews were conducted with industry experts to gather in-depth feedback on the tool's performance and practicality. Surveys were then distributed to a broader audience, collecting quantitative and qualitative data on the tool's usability and accuracy. Additionally, focus groups were organized to facilitate discussions among experts, providing qualitative insights and identifying areas for further improvement. These combined validation methods ensured the tool was rigorously tested, refined, and ultimately became a robust solution for assessing and managing project complexity.

CHAPTER 4: DEVELOPMENT OF PCAM 2.0

In previous chapters, a general summary of the original PCAM tool was presented, showcasing its role in effectively managing project complexity. Despite its strengths, there is a significant need to refine the tool to enhance its applicability and efficiency in contemporary construction project management.

The refinement of the original PCAM tool primarily focuses on enhancing its user-friendliness by applying cognitive psychology principles. One key aspect is reducing cognitive load, ensuring that the tool does not overwhelm users with too much information at once, which can impair decision-making and efficiency (Sweller, 1988). By redesigning the interface to minimize this load, the tool becomes more intuitive and accessible, particularly for those less experienced with such systems.

Attentional resources are another critical area of focus. Effective tool design must help users focus on the most critical information without distraction. This is achieved by using visual cues and organizing information in a way that aligns with how users process data, enhancing both the usability and effectiveness of the tool (Wickens & McCarley, 2008).

Memory load is a key consideration in the refinement process. By creating an interface that minimizes demands on users' short-term memory, such as using visual reminders or simpler navigation paths, the tool can improve user interaction and decrease the potential for errors. This strategy draws on principles from cognitive psychology that explain how optimizing information retention can enhance tool design (Baddeley, 1992).

Lastly, aligning the tool with users' mental models is essential for intuitive interaction. Tools that match users' expectations and cognitive models are easier to use and require less training. By designing interfaces that are aligned with common mental models, users can interact with the tool more naturally and with greater effectiveness (Johnson-Laird, 1983).

Enhancing PCAM's predictive capabilities is also a critical area of focus. While the current tool offers valuable insights into project complexity, incorporating advanced data analysis features could transform it into a more predictive instrument. This would allow project managers to anticipate potential challenges more accurately and make informed decisions early in the project lifecycle. Although integrating AI could be a future direction for the tool, this thesis focuses on refining it as an Excel-based tool to ensure it remains accessible and straightforward for users without advanced technological resources.

Overall, the refinement of the PCAM tool aims to make it more user-friendly and effective by incorporating these cognitive psychology principles into its design. This ensures that the tool not only meets the modern needs of project management but also supports users in managing the complexities of today's construction projects more efficiently. The subsequent sections of this chapter will detail the specific enhancements made to the tool, outline the methodology employed in the refinement process, and assess the impact of these changes through initial testing phases.

4.1 Detailed Review of the Original PCAM Tool

CII is established in October 1983 and based at the University of Texas, is a not-for-profit think tank that fosters collaboration among industry professionals, including successful engineers, contractors, top suppliers, and owners of Fortune 500 companies. Initially comprised of 14 charter members, CII's organizational principles emphasized research conducted by university faculty and graduate students, with substantial industry input (Tucker, 2007). This partnership between academia and the construction sector has yielded numerous practical research products that have significantly enhanced project outcomes. CII's work is particularly critical as 98% of mega projects experience delays and budget overruns. Nevertheless, their initiatives have resulted in an 88% increase in workplace safety and a 16% improvement in material management, translating to savings of $8 million per $100 million spent. Serving various sectors like energy, manufacturing, and space exploration, CII is dedicated to improving the people, processes, technology, and business models essential to the industry's advancement (Construction Industry Institute Website, 2024).

The RT-305 tool, developed by CII, serves as the Project Complexity Assessment and Management (PCAM) Tool, aimed at facilitating the identification, assessment, and management of complexities in large-scale projects. Despite its comprehensive framework and structured approach to complexity management, a significant challenge noted by users is the tool's lack of user-friendliness and the complexity of its scoring system, which can be daunting for project teams.

The original PCAM Tool operates through a more difficult to learn process. Initially, background information about the project and the evaluators must be given, and then, it requires project teams to identify relevant complexity attributes and indicators, which are then assessed and scored within the tool’s Excel-based interface. The complexity of the scoring mechanism, however, has been highlighted as a barrier, making the tool less accessible for those not familiar with its intricacies. This has led to its underutilization, as teams find it burdensome to navigate and integrate into regular project management routines.

Recognizing these limitations, the tool's benefits in early detection of project complexities and its ability to facilitate strategic planning through quantitative complexity measurements are still highly valued. The tool's outputs, including management strategies for each complexity indicator and visual representations such a radar diagram, provide crucial insights for project management. These features help in prioritizing complex project areas and allocating resources more effectively.

To address the usability issues, the original PCAM tool has been refined, aiming to enhance its user interface and simplify the scoring process. The refined tool is designed to be more intuitive, allowing users to navigate its features with greater ease and apply its insights more directly to project management practices.

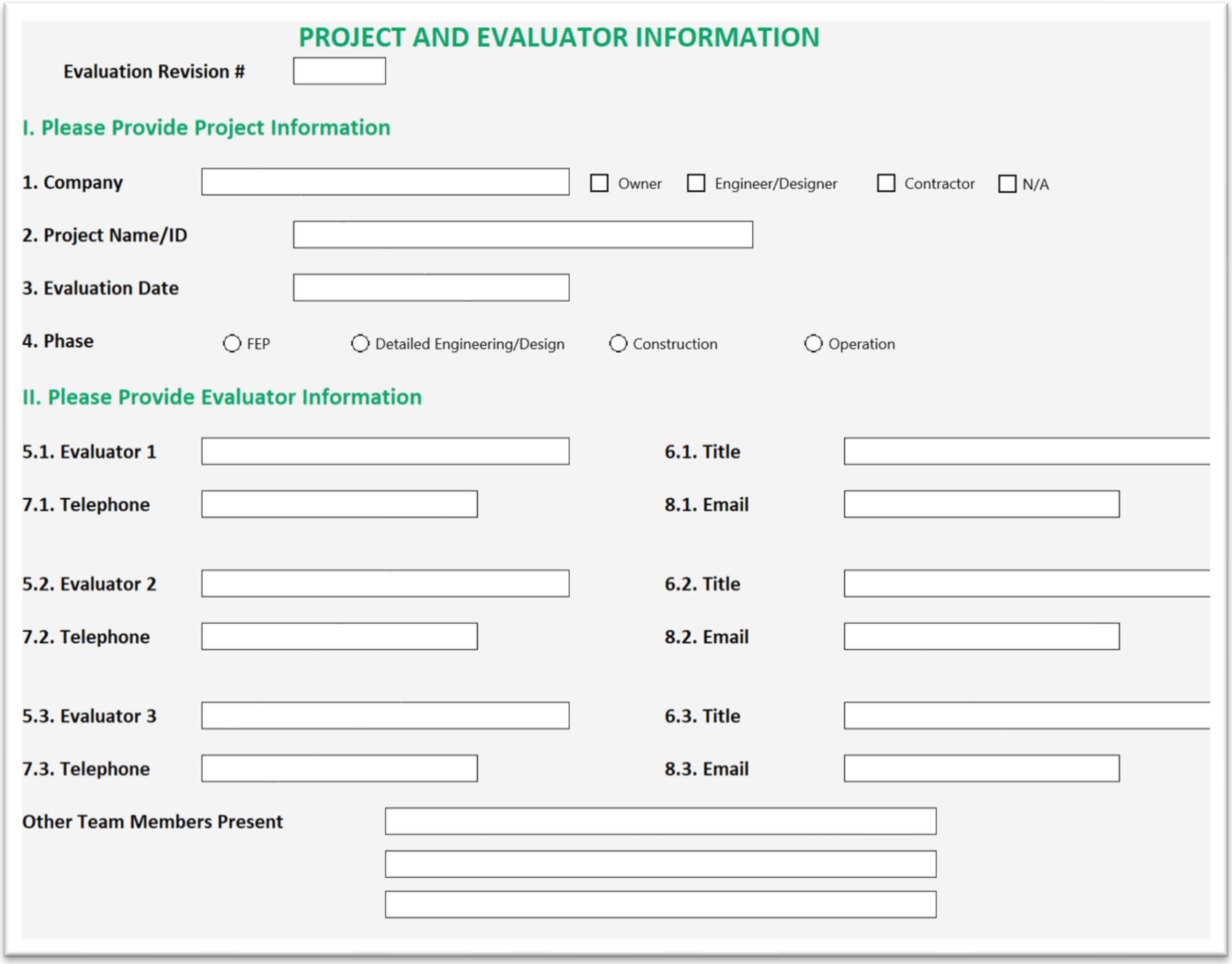
While the original PCAM Tool was developed through collaborative efforts of industry and academic professionals from CII, the refined version builds on this foundation. It maintains the same structured approach to managing project complexity while making it more accessible and less intimidating for users across various project environments.

Overall, the original PCAM Tool has had a significant impact on organizational practices by providing a systematic method to understand and manage project complexity. The refinements made are intended to broaden its appeal and usability, ensuring that more project teams can benefit from its robust framework without being overwhelmed by its complexity, thereby enhancing overall project performance and strategic outcomes.

The original PCAM tool is structured around a methodical framework designed to evaluate project complexity comprehensively through a set of four expanded categories. These categories effectively cover eleven attributes of project intricacies including Stakeholder Management, Governance, Fiscal Planning, Quality, Legal issues, Interfaces, Execution Targets, Location, Scope Definition, Project Resources, and lastly Design and Technology. Each category is carefully tailored to address specific attributes of complexity within the project.

Within these categories, the tool integrates a total of 37 complexity indicators. These indicators are formulated as statements that directly reflect the complexities associated with each category, providing a detailed and nuanced view of potential challenges. This structured approach allows project managers to identify and assess the various attributes of complexity in a comprehensive manner.

After providing background information about the project and the evaluators (Figure 4.1), the user is directed to a complexity assessment page. Here, they must choose a complexity level from nine given options for each of the 37 complexity indicators. These options vary depending on the indicator; for some, the scale may range from 1 to 9, where 1 represents low complexity and 9 represents the highest complexity. For others, the options could include time frames in weeks or other relevant measures, allowing users to select the option that best reflects the complexity level in their project (Figure 4.2).



PROJECT AND EVALUATOR INFORMATION

Evaluation Revision #

I. Please Provide Project Information

1. Company ☐ Owner ☐ Engineer/Designer ☐ Contractor ☐ N/A

2. Project Name/ID

3. Evaluation Date

4. Phase ○ FEP ○ Detailed Engineering/Design ○ Construction ○ Operation

II. Please Provide Evaluator Information

5.1. Evaluator 1 6.1. Title

7.1. Telephone 8.1. Email

5.2. Evaluator 2 6.2. Title

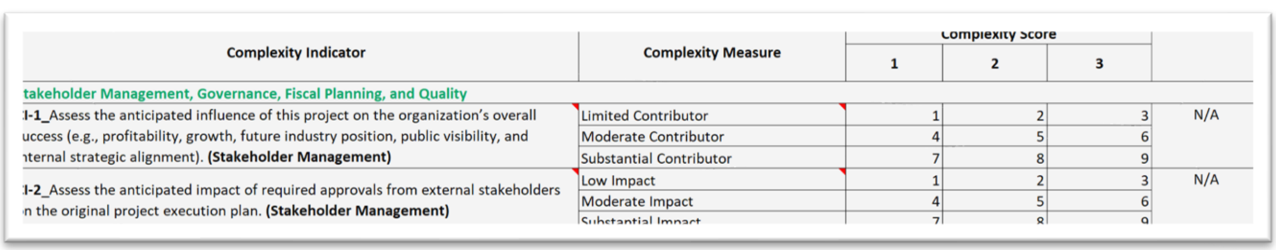
7.2. Telephone 8.2. Email

5.3. Evaluator 3 6.3. Title

7.3. Telephone 8.3. Email

Other Team Members Present

Figure 4.1 *Original PCAM - Info Page*



Complexity Indicator	Complexity Measure	Complexity Score			
		1	2	3	
takeholder Management, Governance, Fiscal Planning, and Quality					
I-1_Assess the anticipated influence of this project on the organization's overall uccess (e.g., profitability, growth, future industry position, public visibility, and nternal strategic alignment). **(Stakeholder Management)**	Limited Contributor	1	2	3	N/A
	Moderate Contributor	4	5	6	
	Substantial Contributor	7	8	9	
I-2_Assess the anticipated impact of required approvals from external stakeholders n the original project execution plan. **(Stakeholder Management)**	Low Impact	1	2	3	N/A
	Moderate Impact	4	5	6	
	Substantial Impact	7	8	9	

Figure 4.2 *Original PCAM -Complexity Score*

Following the scoring process, the user is taken to a page displaying four different radar diagrams and a speedometer that visualizes the complexity levels. These tools help to either show the overall project complexity level or break down the complexity level for each indicator within its respective category (Figure 4.3). However, presenting five different diagrams may increase the cognitive load for the user, potentially making it more challenging to quickly interpret the data and draw meaningful conclusions. This could lead to a need for further refinement in the tool's interface to balance detail with ease of use.

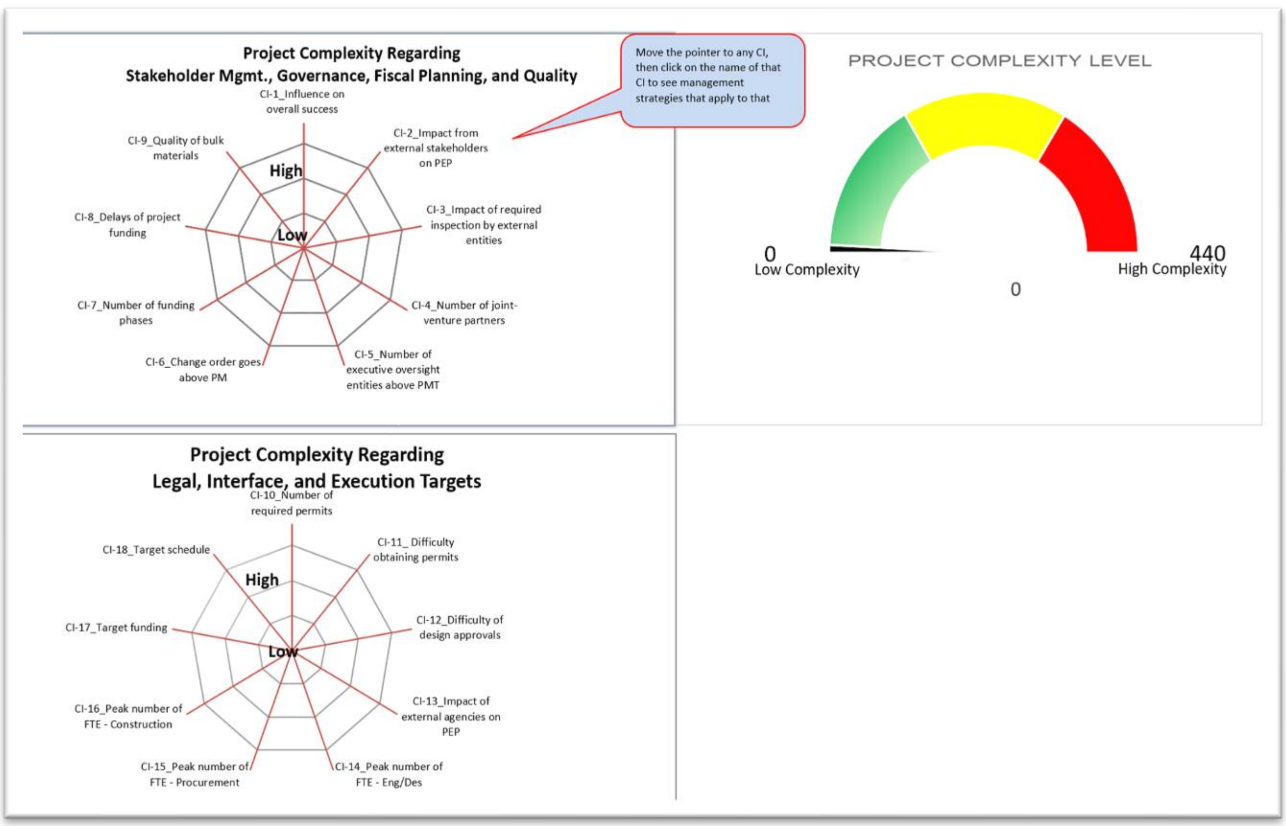


Figure 4.3 *Original PCAM - Radar Diagrams & Speedometer*

On the subsequent pages, the user is provided with a detailed list of management strategies for each of the complexity indicators they scored. This list is heavily worded and tailored to offer actionable strategies designed to manage the identified complexities effectively. This comprehensive process ensures that project managers are equipped with all necessary information to address and mitigate project complexities effectively (Figure 4.4).

OP TEN COMPLEXITY INDICATORS AND RELATIVE MANAGEMENT STRATEGY

Top ten Complexity Indicators (CIs) and relative Management Strategy are selected among 37 CIs based on their relative omplexity score. Complexity score of each CI is calculated based on its complexity factor that was generated from research nalysis and complexity impact level (from 1 to 9) that is assessing by the project team.)

No.	Complexity Indicator	Management Strategy	Additional Strategy
1	CI-2_Assess the anticipated impact of required approvals from external stakeholders on the original project execution plan	1. Develop a Stakeholder Management Plan to identify external stakeholders who have a claim on the project value, understand the claim and define how this claim will be satisfied or avoided. Assign the plan development and management to individual skilled in interfacing with senior management and external entities. 2. Establish a Governance Team and with that team establish a Key Principles (Project Objectives) document. This document must identify and prioritize project objectives and be approved by the Governance Team. The plan should include stakeholder needs and value proposition and decision making process. CII Publications: EM113-21 3. Retain a consultant to identify and interface with external stakeholders. The consultant must be familiar with the local project environment and understand the influence the project will have on the local political environment	
2	CI-5_Anticipate the number of executive oversight entities above the project management team who will have decision-making authority on the project execution plan	1. Limit the oversight decision-making authority to only one above the project management team. This can be a person or group with a clear delegation of authority. 2. Develop a process for expeditious decision-making when time critical issues arise. 3. Have an alignment meeting before the kick-off meeting to discuss the limits of the delegations of authority(s) and the process to achieve results.	

Figure 4.4 *Original PCAM - Management Strategies*

4.2 Methodology for Tool Refinement

The iterative design process was a fundamental approach in refining the new tool, leveraging the cycle of continuous improvement to ensure the tool met its objectives effectively. Here's how the iterative design process was structured to refine the new complexity assessment tool:

1. Planning and Analysis: Initially, specific needs and gaps in the existing complexity assessment tools were identified by implementing and using the tool on multiple projects and getting feedback from different users. Various limitations were identified but the research is particularly focusing on user-friendliness, developing a more intuitive tool. The objectives for the new tool are clearly defined, such as simplifying the user interface or enhancing the comprehensiveness of the complexity indicators.
2. Design: With the goals set, a preliminary version of the tool was designed. This included deciding on the layout, the functionalities, and how the complexity indicators would be presented and interacted with by the users. The design phase focused on incorporating the enhanced features intended to address the deficiencies of the existing tool.
3. Prototyping: A prototype of the new tool was developed, which initially might have been a simplified version incorporating the core functionalities. This prototype served as the first tangible version of the tool, ready for initial testing.
4. Testing: The prototype was then tested in actual project settings to observe how it performed. Feedback was gathered from users who were likely to be project managers, engineers, and other stakeholders involved in project complexity assessments.
5. Stakeholder Involvement: Collaboration with CII was integral to refining the tool. Regular meetings were held with CII representatives to present updates and gather feedback. These interactions ensured the tool's development was closely aligned with industry standards and practical needs, allowing for real-time refinement based on expert insights from CII members.
6. Evaluation and Validation: The feedback and data gathered from the testing phase were thoroughly analyzed. The analysis looked for trends in user responses, such as Ease of use, accuracy of the complexity assessments, and any technical issues that arose.

7. Refinement: With the insights gained from the evaluation, the tool was refined. This might have involved making the interface more intuitive, adjusting the complexity indicators for better clarity, or enhancing the backend algorithms that drove the assessments. This refinement was critical to align the tool more closely with user needs and practical applicability.
8. Iteration: The refined tool underwent another round of testing and evaluation. This cycle repeated, with each iteration aiming to improve upon the previous version based on real user feedback and evolving project management practices.

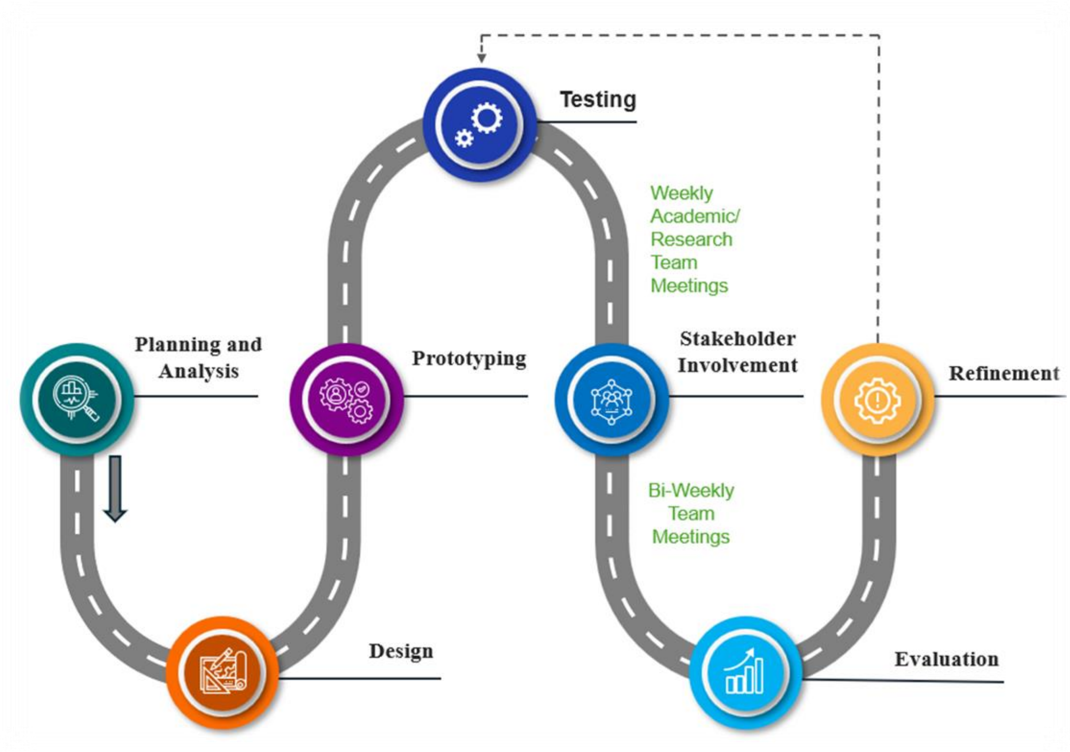


Figure 4.5 *Iteration Process*

Within this process that is shown in Figure 4.5, there was a technical team of individuals from the industry and the academic/research team under the supervision of CII. This team met on a bi-weekly basis to present the latest version of the tool and discuss any needed changes. The academic/research team met on a weekly basis to discuss the technical team's feedback, make and approve changes before meeting with the technical team to present the progress.

This iterative process was crucial in developing a new tool that was not only theoretically sound but also practically effective and user-friendly. By iteratively refining the tool, it was ensured that the tool evolved to meet the changing demands of project management environments, ultimately leading to a robust and reliable resource for assessing project complexity. This approach improved the likelihood that the final product was well-tuned to the needs of its users, maximizing its usefulness and adoption in the field.

4.3 Comparison between PCAM & PCAM 2.0.

PCAM 2.0 offers four assessment approaches to choose from, as depicted in Figure 4.6. Users can select either the General Assessment of Project Complexity, a condensed version of it, an assessment by phase, or an assessment by complexity area.

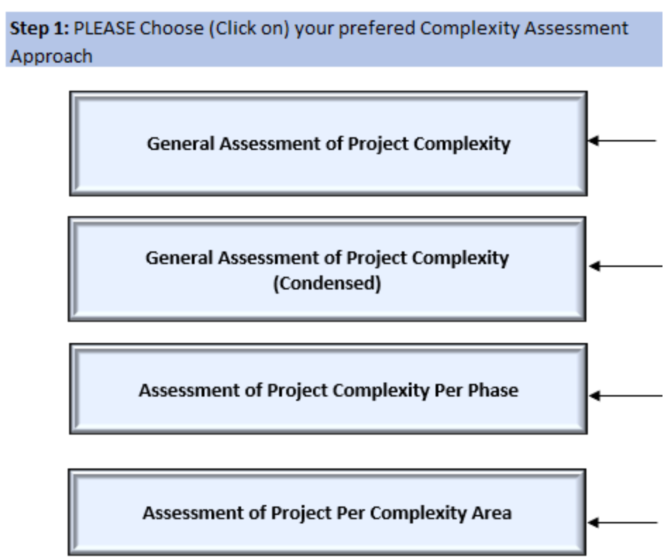


Figure 4.6 *PCAM 2.0 Assessment Approaches*

The first option uses data validated by RT-305, incorporating the same 37 complexity indicators but instead of 11 attributes, PCAM 2.0 has 9 new attributes that cover all 37 complexity indicators (Table 4.1 & Table 4.2). Each of the 37 complexity indicators are incorporated with simpler mitigation strategies, eliminating the need to select a complexity score for each indicator. This change was made because the management strategy provided for each complexity indicator remains constant, regardless of the complexity score assigned.

Table 4.1 *Comparison between PCAM & PCAM 2.0 - Complexity Area/Attributes*

	RT-305 Complexity Areas /Attributes	**RT-398 Complexity Areas /Attributes**
1	Stakeholder Management	Stakeholder Management
2	Governance	Change Management
3	Fiscal Planning	Funding Issues
4	Design and Technology	Technical and System Integration
5	Scope Definition	Labor issues
6	Interfaces	Team Alignment / Communication
7	Project Resources	Resource Constraints/Strain
8	Location	Location Related Challenges
9	Quality	Miscellaneous factors
10	Legal	-
11	Execution Target	-

Table 4.2 PCAM 2.0 – General approach - Complexity Area & Indicator

Complexity Area		Complexity Indicators	
1	**Technical & System Integration**	1	CI-19 Difficulty of system design and integration on this project compared to a typical project for the company.
		2	CI-20 Degree of familiarity with the process technologies that will be involved during the Detailed Engineering/Design phase of the project.
		3	CI-21 Degree of familiarity with the technologies used during the Construction phase of the project.
		4	CI-22 Degree of familiarity with the technologies used during the Operating Facility phase of the project.
2	**Funding Issues**	5	CI-7 Number of funding phases (gates) from concept to project completion.
		6	CI-8 Effort required to obtain project funding.
3	**Resource Constraints /Strain**	7	CI-17 Comparison of target project funding against industry/internal benchmarks.
		8	CI-18 Comparison of target project schedule against industry/internal benchmarks.
		9	CI-33 Planned Vs actual project construction management staff ratio.
4	**Project Management Team Alignment / Communication**	10	CI-4 Number of joint venture partners on.
		11	CI-5 Number of executive oversight entities above the project management team will have decision-making authority on the project execution plan.
		12	CI-14 Peak number of participants (full-time equivalents) on the project management team during the Detailed Engineering/Design phase of the project.
		13	CI-15 Peak number of participants (full-time equivalents) on the project management team during the Procurement phase of the project.
		14	CI-16 Peak number of participants (full-time equivalents) on the project management team during the Construction phase of the project.
5	**Change Management**	15	CI-6 Number of times a change order will need to go above the project manager for approval.
		16	CI-29 Clarity of change management process to key project team members.
		17	CI-30 Impact of change order magnitude on project execution.
		18	CI-31 Impact of change order timing on project execution.
		19	CI-32 significance of how RFIs drive design changes.

Complexity Area		Complexity Indicators	
6	**Labor Issues**	20	CI-34 Quality issues with skilled field craft labor during construction.
		21	CI-36 Craft labor turnover.
		22	CI-37 Availability of local craft labor.
7	**Stakeholder Management**	23	CI-2 Impact of required approvals from external stakeholders.
		24	CI-3 Impact of required inspection by external (regulatory) agencies.
		25	CI-10 Total number of required permits.
		26	CI-11 Difficulty obtaining permits.
		27	CI-12 Difficulty obtaining design approvals.
		28	CI-13 Number of problems the execution plan will face due to external agencies.
8	**Location Related Challenges**	29	CI-23 Number of execution locations during the Detailed Engineering/Design phase.
		30	CI-24 Number of execution locations during the Fabrication phase of the project.
		31	CI-25 Project location's remoteness from highly populated areas.
		32	CI-26 Level of existing infrastructure at site to support construction.
		33	CI-27 Impact of project location on the project execution plan.
9	**Miscellaneous Factors**	34	CI-9 Quality issues with bulk materials.
		35	CI-28 Percent of engineering/design that will be completed at the start of construction.
		36	CI-35 Workarounds (work activities out of sequence) because of material unavailability.
		37	CI-1 Impact of this project on the organization's overall success.

The second option is the condensed version which simplifies the general assessment by reducing the 37 complexity indicators to just 14 under the 9 Complexity area developed by RT-398 (Table 4.3). In this approach, simplified mitigation strategies are also employed, where the complexity indicators with similar strategies are merged to further reduce redundancy. Similar complexity indicators that often correlate are merged as well. Reducing the number of complexity indicators from 37 to 14 streamlines the assessment process, making it less time-consuming and more user-friendly. This simplification helps users focus on the most critical aspects of project complexity.

Table 4.3 PCAM 2.0 – Condensed approach - Complexity Area & Indicator

Complexity Area		Complexity Indicators	
1	**Technical & System Integration**	1	CI-(19-22) Challenges expected with system design and integration (including due to unfamiliarity during design/Construction/Operation).
2	**Funding Issues**	2	CI-(7-8) Funding Challenges expected during project cycle.
3	**Resource Constraints /Strain**	3	CI-17 Comparison of target project funding against industry/internal benchmarks.
		4	CI-18 Comparison of target project schedule against industry/internal benchmarks.
		5	CI-33 Planned Vs actual project construction management staff ratio.
4	**Project Management Team Alignment / Communication**	6	CI-(4,5,14-16) Alignment and Communication Challenges expected due to large/hierarchical project team.
5	**Change Management**	7	CI-(6,29-32) Change magnitude or timing can potentially impact project execution plan.
6	**Labor Issues**	8	CI-(34,36,37) Skilled labor availability/turnover issues
7	**Stakeholder Management**	9	CI-(2,3,10-13) Necessary approvals, inspections, permits expected to pose difficulty.
8	**Location Related Challenges**	10	CI-(23-27) Location related challenges expected to pose challenges during design, fabrication and construction.
9	**Miscellaneous Factors**	11	CI-9 Quality issues with bulk materials.
		12	CI-28 Percent of engineering/design that will be completed at the start of construction.
		13	CI-35 Workarounds (work activities out of sequence) because of material unavailability.
		14	CI-1 Impact of this project on the organization's overall success.

The third approach, as shown in Figure 4.7, assessment by phase, distributes the same 37 complexity indicators across four different project phases: Front End Planning, Engineering/Design, Procurement, and Construction. Specifically, there are nine complexity indicators under Front End Planning, twelve under Engineering/Design, six under Procurement, and ten under Construction. This method allows users to focus on assessing complexity relevant to the specific phase their project is in, simplifying the process by limiting the number of indicators—ranging from six to twelve—to be evaluated per phase.

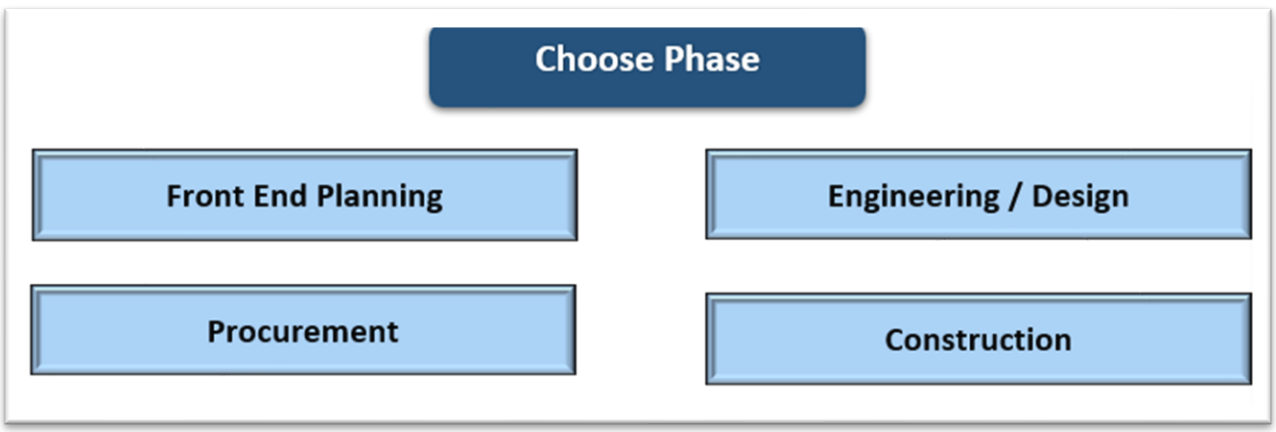


Figure 4.7 *PCAM 2.0 - Third Approach – Assessment by Phase*

The final approach, complexity assessment by Complexity Area (attribute), allocates the 37 complexity indicators across the previously mentioned nine distinct complexity areas, or main attributes: Technical & System Integration, Funding Issues, Resource Constraints/Strain, Project Management/Team Alignment, Change Management, Labor Issues, Stakeholder Management, Location Related Challenges, and Miscellaneous Factors. This structured method enables project managers to concentrate on the complexity attributes most relevant to their projects, enhancing their capacity to develop and implement effective management strategies. By focusing on specific areas, managers can systematically tackle complexities with tailored solutions, thereby mitigating risks associated with particular elements of project complexity. This approach not only simplifies the complexity management process but also improves the accuracy and efficacy of the overall project complexity assessment and management (Figure 4.8)

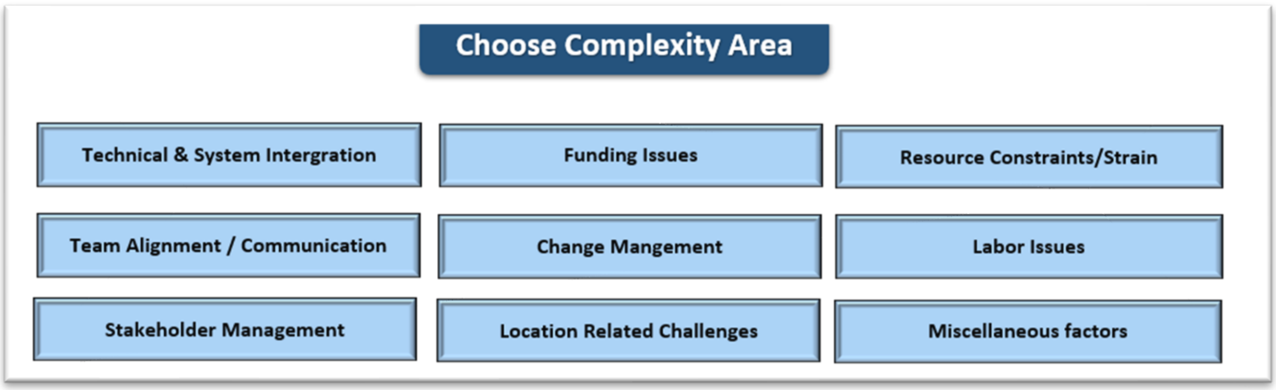


Figure 4.8 *PCAM 2.0 - Fourth Approach – Assessment by Complexity Area*

As shown in Figure 4.9, the RT-305 tool featured a more complex and cumbersome interface, requiring navigation through multiple tabs that provided detailed instructions on its use.

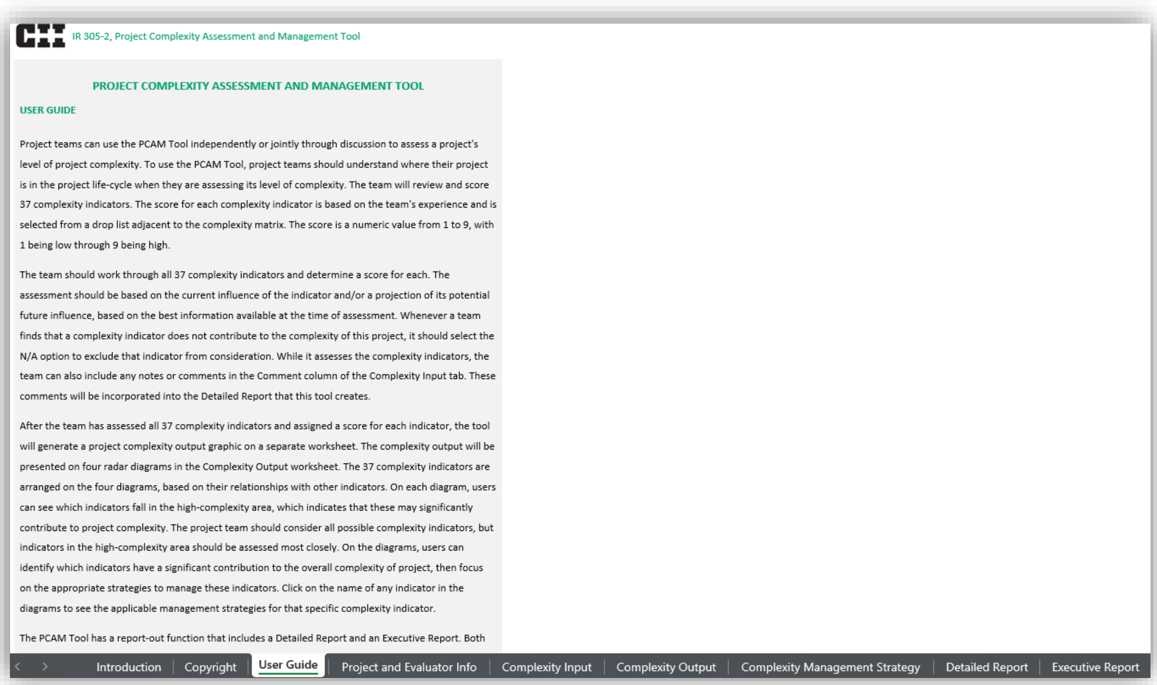


Figure 4.9 *Original PCAM Tool – User Guide*

While in Figure 4.10 PCAM 2.0 tool has streamlined its instructions into a concise two-step bubble on the cover page. This revision reduces the text the user needs to read from 546 words to just 13, as highlighted in Table 4.4.

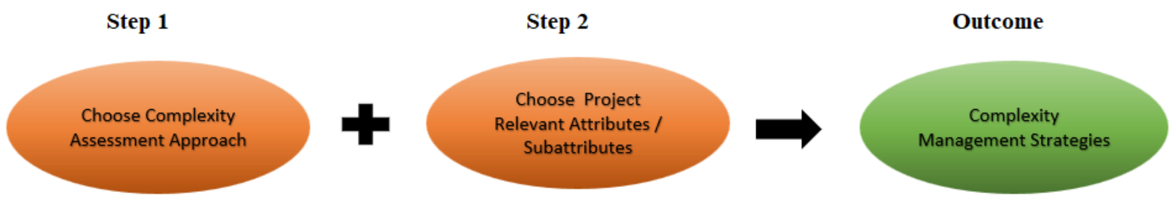


Figure 4.10 *PCAM 2.0 User Guide*

In the original PCAM tool, users were required to manually rate the severity of 37 Complexity Indicators on a scale from one to nine. This process, while thorough, was often time-consuming and could lead to inconsistent results due to the subjective nature of the scoring, and after testing the tool, it was noticed that the management strategies provided for each complexity indicator remains constant, regardless of the complexity score assigned. Recognizing these challenges, PCAM 2.0 introduced several key improvements to enhance user-friendliness and consistency in assessments. One significant refinement was the addition of a reset button on the complexity assessment page, allowing users to conveniently clear selections without the need for manual deselection. Additionally, PCAM 2.0 eliminated the cumbersome scoring system altogether. Instead of assigning severity scores, users now simply select the complexity indicators relevant to their project and apply the corresponding mitigation strategies. This binary approach not only saves time but also reduces variability in assessment outcomes, making the tool more intuitive and effective for users (Figure 4.11).

Attributes		Sub-Attributes	Complexity Management Strategies
Funding Issues	☑	CI-7 Number of funding phases (gates) from concept to project completion	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.
	☑	CI-8 Effort required to obtain 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.

Figure 4.11 *PCAM 2.0 - Binary selection*

Table 4.4 *Comparison between Original PCAM & PCAM 2.0 - Word Count*

	RT-305	RT-398		Change (%) $= \frac{Original - New}{Original} x100$	
		General	Condensed	General	Condensed
Intro	241	111		53.9%	
User Guide	546	13		97.6%	
Complexity Matrix	1595	402	184	74.8%	88.4%
Management Strategy	4552	1758	1620	61.4%	64.4%
Diagrams to read	5	2	1	60%	80%
Typing required	20 cells	Zero		100%	

Table 4.4 demonstrates a significant overall reduction in the word count of the PCAM tool, with an average decrease of 73% across all sections. This substantial streamlining makes the tool more user-friendly by simplifying the information and making it more accessible. The introduction, for example, shows a 53.9% reduction in words, making the initial presentation less burdensome and more engaging for the user. Similarly, the user guide has been drastically

condensed from 546 words to just 13 in PCAM 2.0, maintaining user focus without overwhelming details.

The complexity matrix in the original PCAM tool, which details each complexity indicator along with its severity levels, has seen a marked reduction in word count. Originally requiring more than 1595 words, the general approach in PCAM 2.0 reduces this to around 402 words, a 74.8% decrease. The condensed version further simplifies this to 184 words, achieving an 88.4% reduction. This allows users to quickly grasp the necessary information without sifting through excessive text.

Management strategies associated with each complexity indicator have also been significantly shortened. Originally comprising 4552 words, these have been reduced to 1758 words in the general approach and to 1620 words in the condensed version of PCAM 2.0. This reduction not only simplifies the information but also makes the application of these strategies more accessible to users, promoting better engagement and easier implementation.

Additionally, the diagram section, which helps in visually understanding the tool, shows a substantial reduction in complexity and size, moving from five diagrams to just one or two, reflecting a 60-80% decrease. This simplification helps in focusing user attention on essential information without distraction.

Reducing word count also brings several other benefits such as improved accessibility, making the tool more approachable for users who may have limited time or prefer concise overviews. It enhances clarity, as fewer words decrease the likelihood of misinterpretation, ensuring instructions are understood correctly the first time. This increased efficiency means users can move through the learning or setup phase more quickly and begin applying the tool to their projects sooner. Furthermore, by eliminating unnecessary verbiage, the cognitive load on users is reduced, making it easier for them to focus on the essential aspects of project complexity management. Importantly, these reductions have been carefully implemented to ensure that no original meanings or intended messages are altered, preserving the integrity and accuracy of the information conveyed.

Overall, these changes highlight a deliberate effort to enhance the usability of the PCAM tool, making it less intimidating and more user-friendly. The reductions in word count and simplification of content across the board allow users to engage with the tool more effectively, improving their ability to manage project complexities efficiently.

CHAPTER 5: VALIDATION PROCESS

Validating PCAM 2.0 tool is essential to ensure its effectiveness and reliability when applied to real-world construction and capital facility projects. The primary goal of this validation process is to confirm that the tool accurately assesses project complexity and provides actionable mitigation strategies. Without this validation, the tool may produce misleading results or ineffective guidance, leading to poor project management decisions. Testing PCAM 2.0 in practical scenarios guarantees that it functions as intended and meets industry needs.

A key part of the validation process is evaluating the tool’s usability. As an Excel-based tool, PCAM 2.0 needs to be user-friendly and easily integrated into professionals' daily workflows. The validation will assess whether users can navigate the tool intuitively, input data efficiently, and obtain results without difficulty. Ensuring ease of use is critical for the tool’s widespread adoption in the industry.

Another important focus is assessing the tool’s effectiveness. PCAM 2.0 not only identifies project complexity but also suggests appropriate mitigation strategies. The validation will test if these strategies are practical and effective in real-world applications. If the tool fails to provide useful recommendations, it will not meet its intended purpose.

Additionally, validation will ensure that PCAM 2.0 is relevant to industry professionals. By involving project managers and engineers in the validation process, their feedback will confirm whether the tool addresses the specific challenges they encounter in managing complex projects. This will enhance the tool's credibility and likelihood of adoption.

As part of the validation process, we will also compare PCAM 2.0 with the original PCAM tool. The goal of this comparison is to assess which tool is easier to use and which offers a more streamlined approach to assessing complexity. By examining both tools side by side, we aim to determine if PCAM 2.0 provides improvements in terms of interface, data input, and overall user experience. This comparison will be valuable in identifying whether the modifications made in PCAM 2.0 truly enhance its functionality and make it a more practical tool for industry professionals.

Finally, the validation process allows for continuous improvement. Feedback from industry experts will help identify any areas for refinement, ensuring the tool evolves and remains effective in the changing landscape of project management. In summary, validation ensures that PCAM 2.0 is a reliable, user-friendly, and practical tool for managing project complexity.

5.1 Methodology for Validation

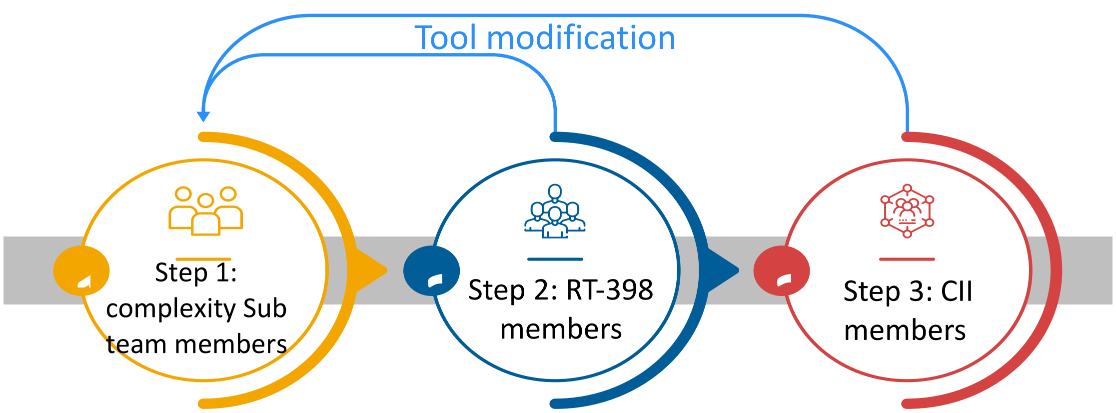


Figure 5.1 *Validation Process*

To ensure that PCAM 2.0 tool is effective and user-friendly for managing project complexity, a structured validation process was implemented. The survey participants included project managers, engineers, and consultants who frequently handle complex projects and would benefit from using PCAM 2.0 tool. This process involved several steps to gather and integrate user feedback from various stakeholders within the construction industry. The RT-398 team, responsible for this validation, was divided into three sub-teams: the Best Practices Sub team, the Complexity Sub team, and the Artificial Intelligence Sub team. Each focused on different aspects of the research. While the team was divided into three sub-teams, the validation process was also structured into three primary steps (Figure 5.1):

1. Initial Evaluation with Complexity Sub Team Members: This step involved a preliminary assessment of the tool's usability and functionality with complexity sub team members who were part of the RT-398 team but not involved in the tool's development. This helped identify any immediate issues or improvements needed before wider release.
2. Extended Evaluation with Full Research Team (RT 398 Members): After incorporating feedback from the complexity sub-team, the tool was then evaluated by the entire RT-398 team, including members from different expertise areas such as the owners or contractors' point of view from the industry world. This provided a more comprehensive assessment from diverse perspectives.
3. Industry-Wide Evaluation with CBAs and Other CII Members: The final step expanded the evaluation to external industry professionals who could provide practical insights into the tool's application in real-world scenarios. This included Communities for Business Advancement (CBA) members ensuring the tool met broader industry standards and needs with the unbiased point of view for not being a part of the development of the tool.

Feedback gathered from each stage of the survey was crucial in refining PCAM 2.0. After each evaluation phase, the tool was adjusted to address the feedback received. This iterative approach helped in progressively enhancing the tool's functionality and user experience, ensuring it met the real-world demands of project complexity management.

5.2 Data Collection and Analysis

The survey utilized a mixed-methods approach, effectively combining both quantitative and qualitative data analyses to deliver a thorough evaluation of PCAM 2.0 tool. Prior to initiating the survey, the research adhered to the Institutional Review Board (IRB) process as outlined in the NCSU policies and regulations. The IRB process is a crucial step in ensuring that the research practices meet ethical standards, particularly in studies involving human subjects. This process was necessary to ensure the protection of the participants involved in the survey and to comply with regulatory requirements, which enabled the collection of data to proceed with institutional oversight (North Carolina State University, 2024)

In the quantitative aspect of the survey, numerical ratings and responses to closed-ended questions were methodically analyzed. This included measuring user satisfaction, where participants rated their contentment with PCAM 2.0 tool using a Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree). Questions such as "The tool provides useful management strategies for project complexity" were crucial for quantifying levels of user satisfaction, enabling a straightforward statistical analysis of the responses gathered.

In parallel, qualitative data was gathered to provide an understanding of the tool's application in real-world settings. Users offered narrative feedback on their specific interactions with the tool. For example, one participant described the tool as "comprehensive, offering flexibility in selecting the right applicable attributes and suggesting appropriate management strategies." Additionally, participants were encouraged to provide suggestions for further improvements. Most feedback was positive, with users appreciating the tool's capabilities. However, one user mentioned, “We still need to simplify where possible, but ultimately, I think it does a good job helping PMs with the assessment."

This integration of quantitative and qualitative data highlights the strength of the methodology, blending precise quantification of user perceptions with in-depth, personalized feedback. Such an approach not only provides statistically significant insights but also captures detailed user experiences, facilitating comprehensive enhancements to PCAM 2.0 tool based on real user needs and feedback. This mixed-methods approach ensures that the tool is continually refined to meet user expectations and industry standards, with the IRB process providing a structured framework to ethically gather and analyze the data.

5.3 Overview of Questionnaire

The questionnaire is designed to gather comprehensive feedback on the usability and effectiveness of the Project Complexity Assessment and Management Tool. The survey starts by collecting basic personal information from participants, including their company type, professional title, and years of experience. This is followed by questions aimed at understanding the participant’s prior experience with the RT-305 tool, including the extent of its adoption in their projects.

Participants are then asked to visualize a recent project they've worked on and apply both the RT-305 and RT-398 tools to assess its complexity. The questionnaire seeks direct comparisons between the two tools, querying which tool was easier to use, which offered a more streamlined approach for assessing complexity, and which tool the participant would prefer to use in their organization for future project complexity assessments.

The core of the questionnaire focuses on the overall evaluation of the RT-398 tool through several statements that participants rate on a Likert scale from 'Strongly Disagree' to 'Strongly Agree'. These statements cover the tool's effectiveness in assessing project complexity, its usefulness in providing management strategies, and its comprehensiveness in capturing all relevant attributes and sub-attributes.

Finally, the survey invites open-ended feedback for improvement, asking participants to suggest any enhancements that could be made to the RT-398 tool to better meet their needs and the demands of managing project complexity.

This questionnaire structure is intended to not only validate the effectiveness and usability of the RT-398 tool compared to its predecessor but also to pinpoint areas for future improvements based on real-world application and user experiences.

5.4 Step 1 and Step 2 of Validation

5.4.1 Audience's Information

As previously discussed in Section 5.1, Methodology for Validation, the validation process was conducted in three steps. This section will focus on discussing the results from the first two steps of the validation. The survey engaged the complexity sub team members and the entire team of RT-398 which is a diverse group of 19 participants, including 6 research team members, 13 industry professionals. The variety of participants' company types, depicted in Figure 5.2, spans 6 distinct categories, highlighting a wide spectrum of expertise with an average of over 25 years of experience among respondents. In terms of response metrics, out of the 19 targeted participants, 15 started the survey and 13 completed it, resulting in a response rate of 79% and a completion rate of 86%.

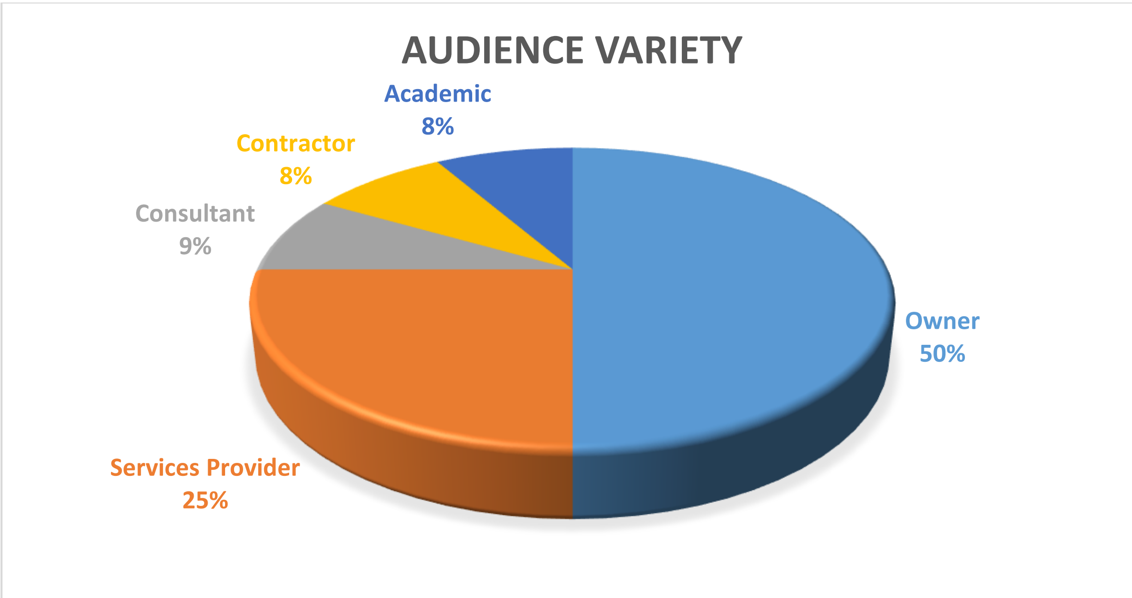


Figure 5.2 *Audience Variety*

5.4.2 Previous Experience with the Original PCAM

As shown in Figure 5.3, the survey results indicate that only 8% of the participants (1 out of 12 respondents) have previously used the RT-305 Project Complexity Assessment and Management tool. This suggests that a vast majority, 92% (11 out of 12 respondents), had no prior experience with the RT-305 tool prior to this study.

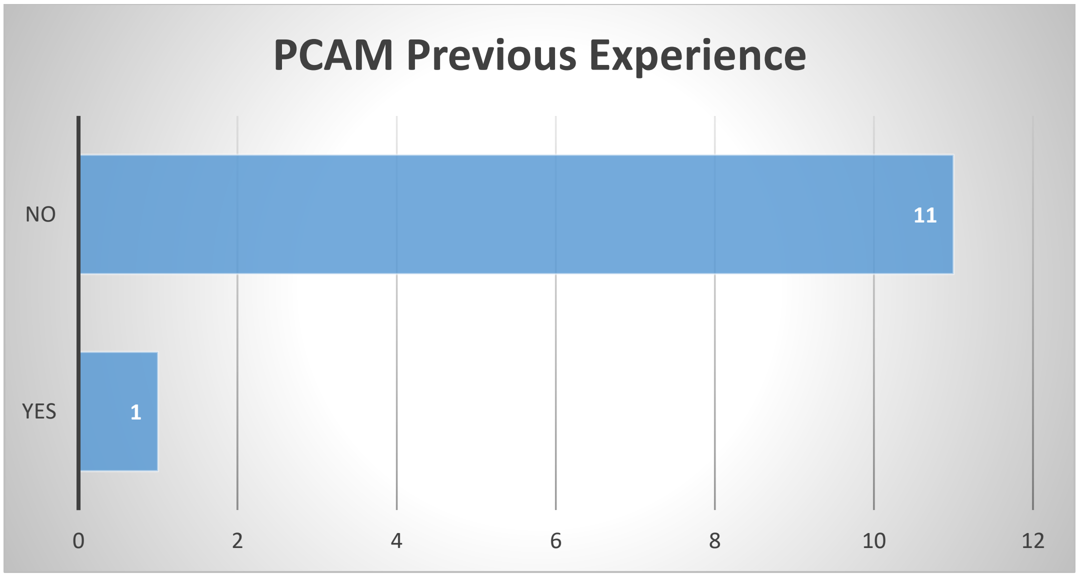


Figure 5.3 Step 1 & 2 - PCAM Previous Experience

This distribution is significant because it implies that the responses to the survey are likely to be unbiased towards the RT-305 tool. Since most participants do not have previous exposure to RT-305, their evaluation of the new RT-398 tool will be based on its own merits, rather than a comparison with an already familiar system. This lack of prior usage could lead to more objective assessments of RT-398's usability, effectiveness, and overall impact, as respondents are not influenced by prior experiences or potential loyalties to the older version of the tool. This context sets a robust foundation for evaluating the RT-398 tool's acceptance among new users, providing clear insights into its standalone capabilities and improvements over the RT-305 tool.

5.4.3 Success criteria and results

5.4.3.1 Tools comparison

In this comparative analysis of the two tools, unanimous preferences were expressed for PCAM 2.0 over RT-305 across three specific questions. The survey results indicate a 100% preference for PCAM 2.0 in terms of ease of use, offering a more streamlined assessment approach and identifying relevant management strategies, and overall tool preference for managing project complexity. This strong alignment across multiple aspects highlights significant enhancements in PCAM 2.0's design and utility, underscoring the importance of incorporating user feedback into the development cycle

5.4.3.2 Evaluation of the RT-398 tool

Success in evaluating PCAM 2.0 tool was defined by several key metrics, including high user satisfaction ratings, precise and reliable complexity assessments by comprehensively capturing all relevant attributes, and the useful application of suggested mitigation strategies. These criteria were designed to ensure that the tool not only meets theoretical expectations but also performs well in practical industry settings. As a measure of success, PCAM 2.0 tool is expected to achieve a high level of user satisfaction, which is indicated by scores averaging above 3.5 on a 5-point scale across all quantitative categories. Participants in the survey were given options on a Likert scale, where "Strongly Disagree" represents 1, "Disagree" represents 2, "Neither Agree nor Disagree" represents 3, "Agree" represents 4, and "Strongly Agree" represents 5.

Table 5.1 *Step 1 & 2 - Quantitative Questions - Evaluation*

	Question	**Results**	**Score**
1	The tool effectively aids in assessing project complexity	(4) Agree (60%) (5) Strongly Agree (40%)	4.4
2	The tool provides useful management strategies for project complexity	(4) Agree (60%) (5) Strongly Agree (40%)	4.4
3	The Tool Comprehensively captures all relevant attributes and sub-attributes necessary to assess project complexity	(4) Agree (70%) (5) Strongly Agree (30%)	4.3

The data presented in Table 5.1 demonstrates a strong level of user satisfaction with PCAM 2.0 tool, as all questions received an average score above 3.5 on a 5-point scale. Here is a detailed analysis of the survey results:

In assessing project complexity, the question regarding how effectively the tool aids in this process received very positive feedback. With 40% of respondents strongly agreeing and 60% agreeing, the tool achieved an average score of 4.4. This high rating reflects that users find the tool very effective in aiding the assessment of project complexity.

Regarding the provision of management strategies, the tool also scored well. The survey asked if the tool provides useful management strategies for project complexity, and again, 40% of users strongly agreed while 60% agreed. This resulted in another average score of 4.4, indicating that users perceive the management strategies provided by the tool as highly useful in addressing project complexity.

For the capability of capturing all relevant attributes and sub-attributes necessary to assess project complexity, the tool scored slightly lower but still high at 4.3. This was due to 30% strongly agreeing and 70% agreeing, suggesting a strong agreement that the tool comprehensively captures the necessary details for complexity assessment.

Overall, step 1 and step 2 of the evaluation indicate that PCAM 2.0 tool achieves a high level of user satisfaction across all evaluated aspects, with an average score of about 4.4 out of 5. This performance not only underscores the tool’s effectiveness in providing support in managing project complexity but also aligns well with the needs of project managers, enhancing their ability to handle complex projects efficiently.

5.4.4 Feedback Summary:

All participants in step 1 and step 2 appreciated the RT-398 tool for its simplified complexity classification and enhanced user experience compared to the older RT-305, which was characterized by overwhelming attributes and multiple radar diagrams. This simplification has made the tool more approachable and easier to use, particularly in environments that demand quick assessments.

Respondents found PCAM 2.0 to be more user-friendly than the original PCAM, particularly praising its simplified interface and streamlined complexity attributes. This redesign has been crucial in enhancing user satisfaction by reducing the cognitive load and making the tool more accessible.

The RT-398 tool was especially favored for its streamlined approach, which effectively reduces ambiguity in complexity rating and simplifies user interaction. By focusing on essential attributes and incorporating a single radar diagram, the tool facilitates easier and more precise assessments. This focus on key elements allows users to quickly understand and apply the tool's insights in real-world project management scenarios.

5.5 Step 3 of the validation

5.5.1 Audience's Information

This section focuses on discussing the results from step 3 of the validation, involving CII members. The survey engaged a diverse group of 11 industry professionals, representing both owner and contractor company types. This group displays an impressive average of over 20 years of experience. In evaluating the survey responses, those that were incomplete were excluded from consideration. This included responses where participants provided only their personal information or uniformly responded with "neither agree nor disagree" on the Likert scale without adding any comments or addressing technical questions. Additionally, responses from non-CII members were omitted from the analysis.

This approach ensures that the results discussed here are derived from fully engaged, experienced industry professionals who are also members of CII, providing a focused and relevant insight into the validation process.

5.5.2 Previous Experience with the Original PCAM

The survey results reveal that 27% of the respondents (3 out of 11 participants) have previously used the original PCAM, indicating that a significant portion of the participants are familiar with the earlier tool. Conversely, 73% (8 out of 11 participants) had no prior experience with RT-305 (See Figure 5.4) This distribution suggests a potential for bias among those familiar with RT-305, as these participants may compare the unfamiliar new RT-398 tool against their experiences with the familiar system. Their familiarity might also result in loyalties to the existing RT-305, reinforced by the time invested in becoming proficient with this tool, whereas they may not have had similar opportunities to familiarize themselves with RT-398, especially in the absence of tutorials or demonstrations.

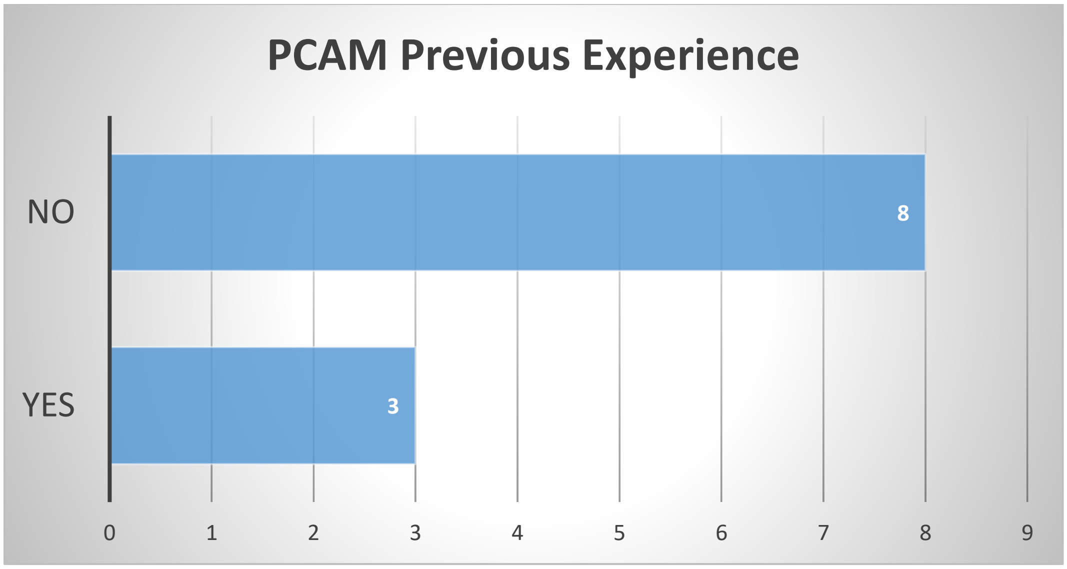


Figure 5.4 *Step 3 - PCAM Previous Experience*

Such familiarity can sometimes lead to resistance to new tools, as individuals often exhibit a preference for tools and methods they have already mastered. This phenomenon, known as the status quo bias, implies that people tend to stick with what they know unless the new option offers significant improvements. Research suggests that overcoming this bias can be challenging; for instance, Samuelson and Zeckhauser (1988) discuss in their paper on status quo bias in decision making that people tend to resist change even when newer options might offer better outcomes.

Given the proportion of respondents familiar with RT-305, their assessments of RT-398 might reflect a resistance to change rather than an objective evaluation of the tool's merits. This context is critical for interpreting the survey results and understanding the dynamics of user acceptance and the transition between different tool versions within the industry.

5.5.3 Success criteria and results

5.5.3.1 Tools comparison

In the comparative analysis presented, user preferences for PCAM 2.0 (RT-398) are clearly demonstrated across three specific criteria as shown in Figure 5.5. The graph highlights user preferences, indicating that PCAM 2.0 is favored for its ease of use, its streamlined approach to assessing project complexity, and its ability to identify relevant management strategies. Notably, the individuals who preferred RT-305 are those who previously stated having previous experience with it, which may influence their comfort and familiarity with the tool. Additionally, when participants were asked which tool they would prefer if both were offered by CII, the majority were leaning towards PCAM 2.0. These results reflect significant improvements in the design and utility of PCAM 2.0, emphasizing the critical role of user feedback in the tool's development process.

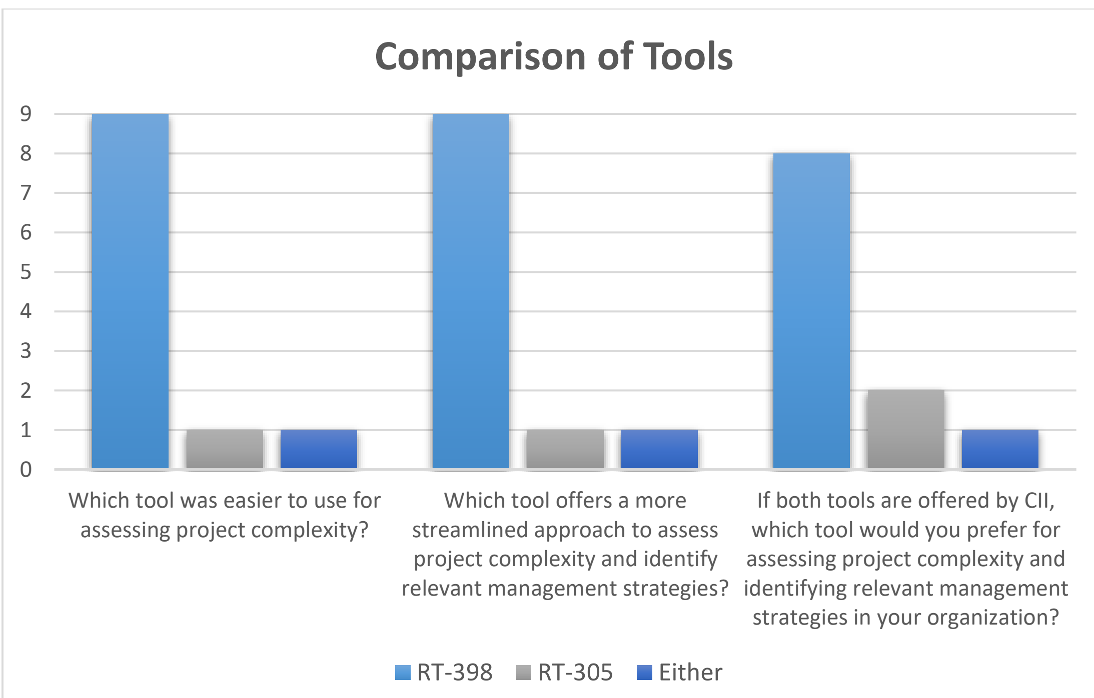


Figure 5.5 *Step 3 - Quantitative Questions - Comparison*

5.5.3.2 Evaluation of the RT-398 tool

Success in evaluating PCAM 2.0 tool was defined by the same metrics used in steps 1 and 2. As a measure of success, PCAM 2.0 tool is expected to achieve a high level of user satisfaction, indicated by scores averaging above 3.5 on a 5-point scale across all quantitative categories. Participants were given options on a Likert scale, where "Strongly Disagree" represents 1 and "Strongly Agree" represents 5.

Table 5.2 *Step 3 - Quantitative Questions - Evaluation*

	Question	Results	Score
1	The tool effectively aids in assessing project complexity	(3) Neither Agree nor Disagree (18%) (4) Agree (64%) (5) Strongly Agree (18%)	4
2	The tool provides useful management strategies for project complexity	(3) Neither Agree nor Disagree (27.3%) (4) Agree (45.4%) (5) Strongly Agree (27.3%)	4
3	The Tool Comprehensively captures all relevant attributes and sub-attributes necessary to assess project complexity	(2) Disagree (9.1%) (3) Neither Agree nor Disagree (27.3%) (4) Agree (45.5%) (5) Strongly Agree (18.1%)	3.7

The data presented in Table 5.2 reveals a generally positive level of user satisfaction with PCAM 2.0 tool. A detailed analysis of the survey results shows that the tool is considered effective in various aspects of project complexity management, though some areas may benefit from further refinement.

When evaluating the tool's effectiveness in assessing project complexity, most respondents (64%) agreed that it is useful, with an additional 18% strongly agreeing. Only 18% of the participants selected "Neither Agree nor Disagree." This yields an overall score of 4 out of 5, indicating that users generally view the tool as effective in helping assess project complexity, demonstrating confidence in its ability to perform this crucial function.

The tool’s ability to provide useful management strategies for project complexity also received positive feedback. A significant portion of respondents (45.4%) agreed that the tool is helpful in this regard, while 27.3% strongly agreed, resulting in a total score of 4 out of 5. Although 27.3% of respondents remained neutral on this point, the overall sentiment is that the tool provides valuable strategies for managing complex projects, with the majority seeing it as beneficial in guiding management decisions.

However, when asked whether the tool comprehensively captures all relevant attributes and sub-attributes necessary to assess project complexity, responses were more mixed. While 45.5% agreed and 18.1% strongly agreed, a notable 27.3% neither agreed nor disagreed, and 9.1% disagreed. The lower score of 3.7 out of 5 in this category suggests that some respondents may have hesitated to fully endorse the tool’s comprehensiveness. This could be due to the inclusion of the word “all” in the question, which may have led participants to feel there is always room for improvement in capturing every necessary attribute.

Overall, PCAM 2.0 tool achieved a strong average score of approximately 3.9 out of 5 across all questions, surpassing the success criteria of 3.5 out of 5. The results indicate a high level of user satisfaction, particularly regarding the tool’s effectiveness in assessing and managing project complexity. This performance not only meets but exceeds the established success benchmark, highlighting the tool's overall effectiveness. However, the feedback suggests that there is room for improvement, especially in ensuring the tool comprehensively captures all relevant attributes. To further validate the tool's effectiveness and utility, additional surveys and refinements may be necessary to fine-tune certain aspects and strengthen its comprehensiveness.

5.6 Feedback Integration and Tool Refinement

The feedback gathered for the RT-398 tool was critical in pinpointing specific areas for refinement and integrating user suggestions to enhance the tool's functionality. Survey responses provided a clear view of the tool's strengths and highlighted necessary improvements. Users expressed a desire for features like a summarized guide for new users, a complexity score at the assessment's conclusion, and a comment section. Some proposed moving away from the Excel-based interface to more user-friendly platforms like Google Forms to increase the interface's interactivity and simplify the complexity assessment process.

Feedback indicated that while RT-398 has significantly improved the user experience over RT-305 by transitioning from over 30 complexity attributes with five diagrams to as few as 14 attributes with a single radar diagram, further enhancements could be made. Users recommended further simplification where possible, minimizing the word count to make it easier for users to engage with the tool. The introduction of a two-step bubble guide in the intro page and streamlined reporting features were direct results of this feedback. These new features are intended to make RT-398 more accessible and user-friendly.

Continuously improving RT-398 through this iterative process ensures that it effectively meets user needs and remains a robust, functional tool for managing project complexity. This responsiveness to user input underscores a commitment to enhancing usability and effectiveness in real-world settings.

5.7 General Sentiment:

The overall sentiment towards PCAM 2.0 tool was initially highly positive during the first two validation steps, with unanimous positive feedback from users praising the tool's organization and the helpfulness of the information it provided. Users also expressed a strong preference for PCAM 2.0 over the older RT-305 model, highlighting its superior functionality and user-friendly interface, which significantly improved ease of use and effectiveness in managing project complexities.

However, the third step of validation revealed a more mixed response, though the feedback still largely met the success criteria set for the tool. Despite the overall positive reception, this phase indicated that there is still some uncertainty among users, suggesting the need for further validation to solidify confidence in the tool. More comprehensive data collection and analysis are necessary to move beyond preliminary approval and to gather definitive evidence of the tool's effectiveness. This approach will help ensure that PCAM 2.0 tool is not only meeting but exceeding project management needs without reservations.

CHAPTER 6: CONCLUSION

This research has effectively addressed the complexities typically found in managing capital facility projects through the development and validation of PCAM 2.0 tool. The initial aim was to enhance the usability and accessibility of the existing complexity assessment tools by refining the original PCAM tool, a tool created by CII's research team 305 making it more user-friendly without compromising its analytical depth. The outcomes of this study have demonstrated that by simplifying the complexity assessment process and integrating straightforward mitigation strategies, PCAM 2.0 tool significantly improves project outcomes and user satisfaction.

The validation process has highlighted the effectiveness of PCAM 2.0 in real-world settings, with feedback from industry professionals affirming its practicality and relevance. The tool has not only facilitated a more straightforward complexity assessment process but also contributed to better project planning and execution by enabling project managers to identify and mitigate potential risks early in the project lifecycle.

While the initial feedback on PCAM 2.0 tool has been largely positive, suggesting its strong functionality and user-friendliness, there is still a need for further validation to achieve a high level of statistical confidence. Although the tool has met the success criteria, some residual uncertainty remains, particularly among users familiar with the original PCAM tool. This indicates that while the tool is effective, more extensive data collection and analysis are required to ensure confidence in its reliability and effectiveness. A more thorough validation process will help move beyond initial approval and provide definitive evidence of the tool's capabilities, ensuring that any lingering doubts or biases are addressed, and the tool is backed by a robust level of confidence in its performance.

Furthermore, the integration of feedback from a broad spectrum of industry professionals has ensured that PCAM 2.0 is responsive to the needs of the industry, thereby increasing its adoption and impact. The success of this tool reflects a significant advancement in the field of project management, particularly in managing the complexities of large-scale construction projects.

The journey of PCAM 2.0 from conception to validation shows a robust model of collaborative innovation that holds significant implications not only for project management but also for the broader construction industry. This research contributes to the body of knowledge in project management by demonstrating the feasibility of simplifying complexity assessments and providing a roadmap for future research to explore additional enhancements and applications of PCAM 2.0 tool. It is hoped that this work will inspire ongoing development in complexity management tools, contributing to more efficient, effective, and successful project management practices across various sectors within the construction industry.

CHAPTER 7: RECOMMENDATIONS

7.1 Recommendations for Future Research

This thesis has effectively established foundational methods for understanding and managing project complexity through the development and validation of PCAM 2.0 tool. Despite these advancements, there remains significant scope for further research to deepen and extend these findings. Future studies could explore the integration of cutting-edge technologies such as artificial intelligence and machine learning, focusing on their potential to predict and mitigate project complexities more proactively. Additionally, applying and validating PCAM 2.0 tool across various industries could offer valuable insights into its adaptability and effectiveness in diverse settings.

Further validation of PCAM 2.0 tool is crucial, particularly to address the mixed feedback observed in later validation stages. It is recommended to conduct a broader validation process, involving a diverse range of CII members who are industry professionals, to assess the tool's effectiveness and gather comprehensive user feedback. This targeted approach will help confirm the tool's utility across different project scenarios and enhance its credibility among key stakeholders.

Conducting longitudinal studies that track the tool's effectiveness across the full lifecycle of projects would also provide a deeper understanding of how complexity management influences project outcomes over time. Comparative analysis between PCAM 2.0 and other complexity assessment tools could illuminate areas where the PCAM tool excels or requires improvements, offering a broader perspective on tool efficacy. Furthermore, investigating the impacts of organizational culture and structure on the management and perception of project complexity could enrich the tool's applicability in different organizational contexts.

7.2 Practical Recommendations

For practical implementation, it is essential to ensure that the enhanced PCAM 2.0 tool meets the specific needs of project managers and integrates seamlessly into daily project management practices. Developing comprehensive training programs tailored to familiarize project managers with the tool’s functionalities and best practices for assessing and managing complexity would facilitate its adoption and utility. Offering customization options for the tool to cater to specific project or industry requirements could enhance its usability and relevance. Moreover, integrating PCAM 2.0 functionalities into widely-used project management software platforms could streamline its application in regular project workflows, making complexity management more accessible to project teams. Implementing continuous feedback mechanisms to collect user insights and update the tool accordingly will ensure that it remains responsive to new challenges and evolving user needs. Lastly, encouraging broader stakeholder engagement in using the tool for complexity assessment could ensure a more comprehensive approach to understanding and managing project complexities, thus fostering greater project success and stakeholder satisfaction.

By following these recommendations for further research and practical application, the contributions of this thesis can be leveraged to enhance project management practices significantly, leading to improved project outcomes and strategic advancements in managing complexities across the construction industry and beyond.

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APPENDICES

Appendix A:

RT-305's List of Attributes and Sub attributes (Original PCAM Tool)

	Attribute	Sub-Attribute
1	Stakeholder Management	CI-1 Assess the anticipated influence of this project on the organization's overall success CI-2 Assess the anticipated impact of required approvals from external stakeholders on the original project execution plan. CI-3 Assess the anticipated impact of required inspection by external (regulatory) agencies/entities on the original project execution plan.
2	Governance	CI-4 Identify the total number of joint venture partners on this project. CI-5 Anticipate how many executive oversight entities above the project management team will have decision-making authority on the project execution plan. CI-6 Anticipate the number of times on this project that a change order will need to go above the project manager for approval.
3	Fiscal Planning	CI-7 Identify the number of funding phases (gates) from concept to project completion. CI-8 Assess any specific delays or difficulties in securing project funding.
4	Quality	CI-9 Assess any quality issues with bulk materials during project execution.
5	Legal	CI-10 Anticipate the total number of permits that will be required. CI-11 Evaluate the anticipated level of difficulty in obtaining permits. CI-12 Assess the difficulty of obtaining design approvals. CI-13 Anticipate how many problems the project execution plan will face due to external agencies.

Attribute		Sub-Attribute
6	Interfaces	CI-14 Assess the peak number of participants (full-time equivalents) on the project management team during the Detailed Engineering/Design phase of the project. CI-15 Assess the peak number of participants (full-time equivalents) on the project management team during the Procurement phase of the project. CI-16 Assess the peak number of participants (full-time equivalents) on the project management team during the Construction phase of the project.
7	Execution Target	CI-17 Compare target project funding against industry/internal benchmarks. CI-18 Compare target project schedule against industry/internal benchmarks.
8	Design and Technology	CI-19 Assess the difficulty of system design and integration on this project compared to a typical project for the company. CI-20 Assess the company's degree of familiarity with the process technologies that will be involved during the Detailed Engineering/Design phase of the project. CI-21 Assess the company's degree of familiarity with the technologies (means and methods) that will be involved during the Construction phase of the project. CI-22 Assess the company's degree of familiarity with the technologies that will be involved during the Operating Facility phase of the project.
9	Location	CI-23 Identify how many execution locations will be used during the Detailed Engineering/Design phase of the project. CI-24 Identify how many execution locations will be used during the Fabrication (bulk materials and equipment) phase of the project.

	Attribute	Sub-Attribute
		CI-25 Assess the project location's remoteness from highly populated areas. CI-26 Assess the level of infrastructure existing at the site to support the project. CI-27 Assess the impact of project location on the project execution plan.
10	Scope Definition	CI-28 Identify the percentage of engineering/design that will be completed at the start of construction. CI-29 Assess how clear the change management process is to key project team members. CI-30 Assess the impact of change order **magnitude** on project execution. CI-31 Assess the impact of change order **timing** on project execution. CI-32 Assess how significantly RFIs drive project design changes.
11	Project Resources	CI-33 Identify the percentage of project/construction management staff who will work on the project, compared to planned project/construction management staff. CI-34 Assess any quality issues with skilled field craft labor during project construction. CI-35 Assess the frequency of workarounds (work activities out of sequence to continue) because materials are not available when needed to support construction. CI-36 Assess the percentage of craft labor turnover. CI-37 Assess what percentage of craft labor will be sourced locally (within 100-mile radius of job site).

Appendix B:

Complexity Assessment Tool (CAT)

The Complexity Assessment Tool			
Areas of complexity Structural Complexity (1–21) Socio-political Complexity (22–32) Emergent Complexity (defined by expectations for stability)		Do you agree with this statement? (Y/N)	Do you expect this situation to remain stable (i.e., NOT to change)? (Y/N)
Structural Complexity			
1	The vision and benefits for the work can be clearly articulated.		
2	Success measures for the work can be defined in agreement with the client.		
3	The technology is familiar to us.		
4	The commercial arrangements are familiar to us.		
5	The scope can be well defined.		
6	Acceptance criteria for quality and regulatory requirements can be well defined.		
7	A schedule and resource plan can be well defined.		
8	The supply chain is in place.		
9	Lines of responsibility for tasks and deliverables can be defined.		
10	Accurate, timely, and comprehensive data reporting is possible.		
11	Existing management tools can support the work.		
12	Sufficient people with the right skills are available.		
13	Managers have adequate control of human resources (i.e., direct reporting).		
14	Key people are wholly allocated to the work.		
15	Integration across multiple technical disciplines is not required.		
16	The budget is sufficient for the task.		
17	The budget can be used flexibly.		
18	The work will be carried out in a single country/time zone/language/ currency.		
19	The work is independent of other projects and business-as-usual operations.		
20	The pace is achievable.		
21	Resources (e.g., test facilities, equipment) will be available when needed.		
Socio-political Complexity			
22	The work has clear sponsorship consistent with its importance.		
23	The business case for the work is clear.		
24	The goals for the work align with the organization's strategy.		
25	Your own senior management supports the work.		
26	Team members are motivated and function well as a team.		
27	Managers are experienced in this kind of work.		
28	The work involves no significant organizational/cultural change.		
29	The work will be unaffected by significant organizational / cultural change.		
30	The external stakeholders (i.e., not immediate team members) are aligned, supportive, and committed to the project and have sufficient time for the work.		
31	The external stakeholders (i.e., not immediate team members) have a realistic, shared understanding of the implications of the work.		
32	The core team has the authority to make decisions.		

Appendix C:

Success Criteria Calculation for Likert Scale Results

	Options	Calculation	Range
1	Strongly Disagree	lowest Likert scale, lowest Likert scale + 0.8 (1, 1+0.8)	(1.0 – 1.8)
2	Disagree	(end of previous range + 0.1, end of Previous range + 0.8) (1.8+0.1, 1.8+0.8)	(1.9 – 2.6)
3	Neither	(end of previous range + 0.1, end of Previous range + 0.8) (2.6+0.1, 2.6+0.8)	(2.7 – 3.4)
4	**Agree**	end of previous range + 0.1, end of Previous range + 0.8) (3.4+0.1, 3.4+0.8)	**(3.5 – 4.2)**
5	Strongly Agree	end of previous range + 0.1, end of Previous range + 0.8) (4.2+0.1, 4.2+0.8)	(4.3 – 5.0)

Highest scale – Lowest scale = 5 – 1 = 4

4/number of scales = 4/5 = 0.8

Since success criteria is “Agree”, then the range of success criteria is 3.5 and above.