Final Report DCC-02

Construction Readiness Assessment for Productivity Improvement

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Construction Readiness Assessment for Productivity Improvement

CII Annual Conference 2018 Edition

Prepared by

Construction Industry Institute
Research Team DCC-02, Construction Readiness Assessment
for Productivity Improvement

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Executive Summary

Due to the competitive construction market and the omnipresent pressures of time and money on large-scale projects, project teams often launch into construction without taking time to adequately assess their construction readiness. As such, numerous projects begin construction before they are ready to do so, leading to poor productivity across project activities and unsatisfactory project performance. In addition, some other teams may delay too long past the point of construction readiness, incurring other problems, due to a lack of clarity in definition of construction readiness in today's construction market.

In an effort to tackle this industry-wide problem, the Downstream and Chemicals Sector Committee selected "Construction Readiness Assessment for Productivity Improvement" to be one of its first funded research teams. The goal of this research is to quantitatively determine what qualifies a project as "construction-ready" while assisting project teams to improve and sustain the readiness level of their projects.

In pursuit of these research goals, RT-DCC-02 (hereafter referred to as "the research team"), derived 228 readiness factors from members' industry expertise, the extant body of literature concerning construction readiness, and the current state of the practice in terms of construction readiness. These factors were further divided into 15 categories, including Project Team, Engineering, Planning, and Stakeholder Management. Once the factors were identified, a comprehensive survey was developed which collected data from 80 projects. These projects were divided into two sets:

- 41 projects that were Construction-Ready (CR)
- 39 projects were Construction-Not-Ready (CNR).

The next step was to determine the relative importance of the factors. Using the collected data, the team developed mathematical and statistical models to weight each factor, facilitating their comparison and the determination of importance.

The following factors had the highest weights in differentiating CR from CNR projects:

- Engineering factors – factors related to the development process of Issued-For-Construction (IFC) drawings
- Project Team factors – factors related to forming a multidisciplinary skilled team
- Planning factors – factors related to accounting for projects' hold points and handoffs.

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From these weights, the Construction Readiness Score (CRS) is computed. This single, unified metric allows the easy comparison of a project to itself over time (i.e., is this project becoming more ready through the actions of the project team) or to other projects executed by a company (i.e., is this project more or less ready than previously performed projects). The score is calculated by the Construction Readiness Assessment Tool (CRA), which not only calculates the CRS but also compares it to data-defined benchmarks for readiness as well as user-defined project goals. The CRA also identifies leverage areas that a project team may use to improve their readiness or maintain it over a project's duration. The final version of the tool was tested on 10 real-world projects, all of which reported that not only was the tool accurate in its evaluations of construction readiness, but also was useful in directing the efforts of the project team to become more ready. Additionally, the testers found the tool exceptionally user-friendly, and each one of the testers planned to use the tool on future projects.

In order to underscore the importance of being CR before proceeding, the research team then quantified the importance of construction readiness by assessing the performance of CR projects as compared to CNR projects. It was found that that CR projects exhibit the following advantages:

- 22% schedule reduction on average
- 29% productivity improvement
- 20% cost savings
- 7% less rework
- 21% less change, relative to CNR projects.

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Chapter 1
Introduction

In terms of both economic influence and impact on the everyday life of citizens, the construction industry is one of the most significant industries to any nation. In the United States, the construction industry accounted for $1.2 trillion in annual spending, per the U.S. Census Bureau (2017). This figure is projected to increase to $1.4 trillion by 2020, per the U.S. Bureau of Economic Analysis (2017). Furthermore, approximately 5% of the U.S. labor force is employed by the construction industry, or approximately 8 million people, which is unsurprising given the labor-intensive nature of construction work (U.S. Bureau of Labor Statistics, 2017). However, despite its voracious appetite for labor, increased financial investment, and even recent innovations in technology, the construction industry is not getting any more efficient. In fact, for decades construction productivity has been declining while other industries have gained. Since 1960, construction productivity is down over 30%, while non-farm industries (i.e., automotive, aerospace, medical, etc.) have doubled their productivity over the same period (Teicholz 2013; Hanna 2010). Nowhere is this treacherous trend in productivity more evident than in megaprojects (i.e., those projects which are worth $1 billion or more). Changali et al. found that 98% of megaprojects experience cost overruns or delays, with an average cost increase of 80% and schedule slippage of 20 months (2015). Productivity loss across all construction projects is estimated to cost the global economy more than $1.6 trillion annually (Barbosa et al. 2017). This perturbing statistic is the impetus behind a great number of productivity studies, including this one.

1.1 Readiness as a Persistently Missing Piece

Since its inception, the Construction Industry Institute (CII) has funded numerous research efforts into the specific factors which cause loss of productivity in construction. The results of these studies have produced numerous landmark publications, enumerated in Table 1. Although many of the factors addressed in these publications correlate with inadequate construction readiness, the assessment of construction readiness as a whole remains a persistent missing piece in the body of literature. A stand-alone study was needed to rectify this missing piece. Accordingly, CII commissioned RT-DCC-02 to address this persistently missing piece.

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Table 1. Sample of Factors Related to Poor Productivity Addressed by CII Research

Examples of Factors Related to Poor Productivity and Addressed by CII Research	CII Research Teams
Project Change and Cumulative Impact of Change Orders	RT-27 RT-158
Overtime and Fatigue	RT-2 RT-33
Errors and Omissions in Plans and Specs	RT-10
Insufficient Engineering Drawing Management	RT-215
Poor Material Management Practices	RT-257
Poor Coordination between Trades	RT-272
Unsafe Working Conditions	RT-284
Shortage of Skilled Labor	RT-182
Late Deliverables	RT-300
Premature Starts	RT-323
Out-of-Sequence Work	RT-334
Insufficient Construction Readiness	RT-DCC-02

1.2 Research Objectives

RT-DCC-02 defines construction readiness as "a series of activities and procedures that should be completed or substantially completed prior to construction to productively start and sustain construction operations."

The objective of this research was to create a user-friendly tool that can:

1. Quantitatively assess the construction readiness of a project
2. Assist project teams in improving and sustaining the construction readiness of their projects by:
   a. Pinpointing missing key factors and leverage areas
   b. Organizing project-specific preventive and corrective actions while recommending relevant best practices
   c. Tracking progress related to construction readiness

Additional objectives that the research team set were:

1. Quantitatively measure the degree to which Construction-Ready (CR) projects outperform Construction-Not-Ready (CNR) projects
2. Validate the benefits and usability of the CRA tool by conducting a pilot study on real-world projects.

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1.3 Research Scope

The scope of this research is the Engineering, Procurement, and Construction (EPC) industry, with emphasis placed on the construction period and related pre-construction activities. While the primary focus of the research is the downstream and chemicals sector, the findings of the research are applicable to all construction sectors.

The research team sought to provide information that is actionable for project stakeholders. As such, the factors identified and examined include only those factors which are within the control of the project stakeholders. *Force majeure* factors (a.k.a. Acts of God) were excluded.

1.4 Research Methodology

The research process can be broken down into six primary tasks, each with defined sub-tasks. These tasks are elaborated upon in the following sections of this report.

1.4.1 Literature Review

As was stated previously, the factors considered in this research effort were partially derived from extant literature on construction readiness. Therefore, the initial phase of this research comprised a comprehensive literature review of publications concerning construction readiness and its related factors. The scope of this literature review included not only CII publications but also works published in major journals (e.g., the ASCE *Journal of Construction Engineering and Management).* The literature review is located in Chapter 2 of this report.

1.4.2 Development of Readiness Factors

The team developed 228 readiness factors using both the reviewed literature and the industry expertise of its members. These factors spanned 15 categories, including Project Team, Engineering, and Planning. The development process for the readiness factors is located in Chapter 3.

1.4.3 Data Collection and Overview

In order that the factors might be weighted, data from industry projects was needed. A comprehensive survey was developed to collect this data. The respondents to the survey provided both qualitative and quantitative data from 80 real-world projects, which were then subdivided into two classes:

- 41 CR projects
- 39 CNR projects.

Survey development, distribution, and data collection are discussed in Chapter 4.

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1.4.4 Data-driven Findings

Using the collected data, the research team developed mathematical and statistical models to compute a relative weight of importance for each of the 228 readiness factors based on the differentiation between CR and CNR projects. These weights were then used to compute an overall project construction readiness score as a percentage. Based on the scores computed, benchmarks were identified which characterized projects as CR, Borderline, or CNR. To prove the cruciality of adequate construction readiness, the research team then compared the performance of CR projects to CNR projects. (A discussion of the data-driven findings is located in Chapter 5.)

1.4.5 Construction Readiness Assessment (CRA) Tool

In order to ensure that the findings of this research were accessible and applicable to as many projects as possible, the Construction Readiness Assessment (CRA) tool was developed. This tool uses the derived weights of the readiness factors to compute a project-specific readiness score. This score is then compared to the benchmarks identified in this research to place the project in one of the three identified categories (CR, Borderline, CNR), as well as user-defined goals for the project. Furthermore, the CRA tool identifies leverage areas of improvement to increase a project's level of readiness, and suggests relevant best practices to address the leverage areas. Repeated use of the tool on a project is recommended, as over time the tool can track a project's progress towards construction readiness, or if readiness has been achieved the tool can ensure it is sustained. The CRA tool is discussed in greater detail in Chapter 6.

1.4.6 Research Validation

The team beta-tested the CRA tool on 10 projects to validate both its derivation of readiness scores and its ease of use for the practitioner. These 10 projects also provided data that were used to validate the models and findings of this research effort. (The validation of this research is discussed in Chapter 7.)

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Chapter 2:
Literature Review

While the research team made every effort to encompass the widest possible range of literature, nevertheless no studies were solely devoted to evaluating construction readiness. Many studies discussed construction readiness as an aside or included it in their recommendations for future research. As a result, much of the information that the research team was able to gather was winnowed out of studies that only tangentially related to construction readiness. What follows is a sample of the most pertinent literature to evaluating construction readiness.

2.1 Readiness Assessment-Related Studies

CII Research Team 311 (RT-311) conducted a study entitled *Successful Delivery of Flash-track Projects*. This study proposed that the success of flash-track projects was primarily contingent on the readiness of the company executing. To that end, RT-311 proposed a method to assess readiness levels within the company, as well as guidelines to successfully execute flash-track projects. The team identified 47 essential practices across six categories:

1. Planning
2. Execution
3. Organizational
4. Cultural
5. Delivery
6. Contractual

Using the Analytical Hierarchy Approach, the team assigned weights to each practice and developed an assessment toolkit. It is worth noting that RT-311 did not investigate readiness in the context of commencing construction, as this study does. Rather, that team investigated readiness to assume flash-track projects (RT-311 2016).

RT-323 focused more substantially on premature start to construction and mobilization in its study entitled *Finding Leading Indicators to Prevent Premature Starts and Assuring Uninterrupted Construction*. RT-323 identified nine drivers of premature start of construction, 10 leading indicators, and 13 impacts that occur as a result; however, RT-323 did not set out to define a quantitative assessment of readiness beyond the scope of premature start. Also, RT-323 excluded from its scope any actions taken prior to mobilization (RT-323 2016), which can offer a crucial part of the missing piece of construction readiness.

RT-334, whose study was entitled *Best Practices for Preventing Out-of-sequence Construction Activities and Minimizing their Impacts,* investigated the causes, warning signs, and impacts of out-of-sequence work, and was able to identify 88 root causes

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of out-of-sequence work spanning 11 categories. Additionally, the study generated 54 warning signs of out-of-sequence spanning the same 11 categories. Finally, RT-334 proposed more than 180 preemptive and responsive actions, spanning 21 concepts, to prevent out-of-sequence and mitigate its negative impacts. The sheer volume of factors, warning signs, and rectifying actions proposed in RT-334's work dovetails with the work of this research team, as a construction-ready project is more likely to avoid out-of-sequence work and vice versa. Therefore, the factors proposed by RT-334 were given great consideration when this team developed the list of factors used in this research (RT-334 2018).

2.2 Current State of the Practice

In order to supplement the list of factors identified from the literature review, the research team examined the state of the practice of assessing construction readiness. To do so, the team leveraged the experience and expertise of its industry members. It was found that the primary method of assessing construction readiness among the industry team members were proprietary checklists of factors that had been determined in-house. Many of these checklists were incorporated into the consideration process by the research team and a number of their factors are part of the final list.

2.3 Leading and Lagging Indicator of Project Success

CR projects normally outperform CNR projects, and accordingly, high-performing projects are more likely to have been CR prior to commencement. Therefore, the research team investigated leading and lagging indicators of project success in order to find additional indicators of construction readiness. For example, high-performing projects successfully control costs, and therefore an indicator of construction readiness is effective cost control planning. The studies that were reviewed discussed performance areas including cost, schedule, quality and productivity. In addition, communication and stakeholder management were also identified as non-traditional performance metrics. These performance metrics were used both to inform the development of readiness factors and to provide assessment metrics for the comparison of CR to CNR projects. Detailed discussion of relevant studies to each metric follows.

2.3.1 Cost Performance Factors

Cheng (2014) found that cost overrun is a pervasive issue in the construction industry. Therefore, this study investigated which readiness factors influenced costs, using cost overrun as an indicator. This investigation found 16 cost-linked factors that had significant impact on cost performance. Of these factors, clear contractual scope and cost control methods were found to be the major predictors of cost overrun.

2.3.2 Schedule Performance Factors

A Norwegian study conducted by Zidane et al. (2015) investigated the effects of delays and inefficient time management on project success. Zidane et al. investigated which factors may cause a project to perform poorly in terms of schedule management, and identified the frequency with which these factors occur.

The top 10 factors were identified with relative importance rankings from the perspectives of owners, consultants, and contractors. RT-DCC-02 analyzed the factors identified by Zidane et al. to determine which could be controlled prior to construction's commencement – or, in other words, those factors that should inform construction readiness (Zidane et al. 2015).

2.3.3 Quality Performance Factors

Contractors should always strive to deliver their product at the highest level of quality. Hwang et al. (2014) studied nearly 400 projects performed in Singapore, using rework percentage as a metric for quality. It was concluded that approximately 60% of the studied projects (approximately 240 projects) experienced issues with quality. Owners, it was found, were the source of the majority of the required rework. Hwang et al. identified seven causes of owner-initiated rework. RT-DCC-02 sought to preemptively address these causes by incorporating them into its development of construction readiness factors.

2.3.4 Engineering Performance Factors

RT-300 (2015) investigated the impact of late engineering deliverables and other engineering issues on project performance, using metrics of cost, schedule, safety, quality, and organizational performance. As a part of this study, a comprehensive list of engineering-related risk factors was developed. RT-DCC-02 used this list to develop a framework of engineering-related factors that can impact construction readiness (Barry et al. 2015).

2.3.5 Productivity Performance Factors

RT-252 (2013) investigated the degree to which tools, methods, and strategies designed to improve construction productivity are being implemented on jobsites. It was found that only 35-45% of a craftsman's time on the job is attributable to direct work. A product of this research was the *Construction Productivity Handbook*, a standalone reference of means and methods to improve construction productivity. This handbook divided improvement methods into categories in a manner similar to the one used by RT-DCC-02 – categories included: safety, materials management, systems integration and automation, team building, front end planning, and constructability. It

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was claimed by RT-252 that successful implementation of the improvement methods they laid out could improve productivity by up to 50%. RT-DCC-02 was inspired by this information to seek methods and factors that could improve productivity from a construction readiness standpoint.

2.3.6 Commissioning Performance Factors

RT-121 (1999) conducted a study entitled “Planning for Startup: Analysis of the Planning Model and Other Success Drivers” which focused on successful project delivery, commissioning, and startup. Startup was defined as “the transitional phase between plant construction completion and commercial operations, including all of the activities that bridge these two phases.” RT-121 identified eight crucial steps of successful startup: system turnover, checkout of systems, commissioning of systems, introduction of feedstock, and performance testing. They then identified and defined 45 planning activities within these eight steps. These activities were broken down across the eight-phase project lifecycle that begins with feasibility and ends with operations. RT-121 estimated that owners could reduce costs by 7.4% and schedule slippage by 7.9% by controlling these factors. RT-DCC-02 seeks to compound those savings by controlling for startup factors during readiness assessments and preconstruction planning.

2.3.7 Communication and Stakeholder Management Factors

Construction, particularly high-tech construction such as healthcare facilities and power plants, involves numerous teams and stakeholders. All project parties must be able to effectively share information and collaborate. Cheung et al. (2013) demonstrated a high level of positive correlation between communication and project performance. Communication issues were divided into five categories: communication with prospective clients, communication between clients and advisors, communication within the design team, communication relating to the contract, and communication within the construction team. 12 methods of communication that are commonplace in the construction industry were studied. By consulting with experts, Cheung et al. ranked these methods of communication according to their effectiveness, and developed a framework for effective communication. RT-DCC-02 agrees that communication is of paramount importance, and believes that by considering communication factors during readiness assessment, communication within the project and the project as a whole may be made more successful.

As lean ideologies and beliefs become more widespread and accepted in construction, a key factor to understand is the successful integration of project stakeholders. RT-130 (1998) performed a study of the relationship between owners, contractors, and

suppliers. It was found that proper management of stakeholders involves integrating them into the project as early as possible. It was further found that so integrating the stakeholders could generate cost savings of up to 8% and schedule savings of up to 15%. In addition, it was found that early involvement of downstream stakeholders can further increase the realized savings. As early involvement logically includes preconstruction involvement, RT-DCC-02 paid special attention to developing factors to ensure that the findings of RT-130 were incorporated in the readiness score.

2.4 Literature Gap

After the literature review was concluded, it was apparent that there is an extremely limited body of literature that solely focuses on construction readiness. Instead, the existing body of knowledge discusses construction readiness indirectly or alongside another issue or issues.

From such literature, some information about factors that affect readiness (as they pertain to other specific issues), recommended actions to achieve readiness, and impacts of being not-ready could be gleaned from logical correlation and induction. However, as no source addressed construction readiness from a broad perspective, this research seeks to close this gap in the body of knowledge by:

1. Providing a comprehensive list of factors that affect construction readiness
2. Weighting the factors to identify the most leverageable areas to improve readiness most effectively
3. Developing a scoring system along with benchmarks to determine if a project is Construction-Ready (CR) relative to industry standards.
4. Analyzing the performance of CR vs. Construction-Not-Ready (CNR) projects to quantify the impact of being ready before proceeding.

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Chapter 3:
Generation of Readiness Factors

As was previously stated, the primary objective of this research is to measure construction readiness in order to differentiate construction-ready (CR) and construction-not-ready (CNR) projects. In order that construction readiness can be measured, a comprehensive list of construction readiness factors was generated. This constitutes a qualitative assessment of readiness. As RT-DCC-02 also wished to generate a quantitative assessment method that could inform the creation of the automated assessment tool, the next step was to weight the factors to allow the development of the overall CR score.

3.1 Initial List and Development Process

The initial list of CR factors was derived from the literature review and the expertise of team members. This list amounted to 90 total factors across 11 categories, as shown in Figure 1. Each of the factors was designed to be answerable on a five-point Likert scale. The team used the Kawakita Jiro (KJ) method to define the first draft of the factor list. The KJ method is a group consensus technique which allows the organization and prioritization of data (like qualitative factors).

Figure 1. Distribution of Initial Factors List (LRF #1)

The team then met to review and refine this initial list by adding new factors to fill in gaps, editing factors for clarity and combining duplicate or overlapping factors. This first round of revision expanded the total number of factors to 111 across the same 11 categories, as shown in Figure 2.

Figure 2. Distribution of Second Draft of the List of Readiness Factors (LRF#2)

At the team's next meeting, it was decided that rather than the original Likert scale, a binary (i.e., yes or no) scale would be more accurate, less subjective, and more user-friendly. As such, the factors list was once again edited to make each one binary. This necessitated the splitting of several factors into less complex sub-factors. As a result, the factors list expanded to 210 factors across 15 categories as shown in Figure 3.

Continuing the team's efforts, a final round of revisions was performed which expanded the list to its final size of 228 factors across 15 categories. This final distribution is presented in Figure 4. As can be seen, the final list of readiness factors is grouped into 15 categories, which range in their number of component factors from five factors to 27 factors per category. It is important to note that simply because a category has more factors in it does not mean that it is more important or a more likely predictor of readiness than a category with fewer factors. Instead, the number of factors per category should be understood as an indicator of the type of category. A category with more factors is indicative of a higher level of detail and consideration put in place by the project team before construction. Additionally, the number of factors per category is indicative of that category's pertinence to preconstruction activities. For example, "planning" obviously is highly correlated with preconstruction activities, and as such has a higher number of associated factors.

Figure 3. Distribution of Third Draft of the List of Readiness Factors (LRF#3)

Figure 4. Distribution of Final List of Readiness Factors (FLRF)

3.2 Final List of Factors

Table 2 lists the final 15 categories, along with the numeric code that was assigned to each and the number of factors each included.

Table 2. Numeric Code for Categories and Corresponding Number of Factors

Category	Number of Factors
Project Team	24
Engineering	17
Planning	27
Health/Safety/Security/Environment (HSSE)	20
Execution	21
Tools and Equipment	13
Quality Management	12
Change Management	15
Contract Management	15
Human Resource Management	17
Stakeholder Management	5
Risk Assessment and Management	5
Procurement and Material Management	14
Commissioning	14
Project Controls	9

Table 3 presents an excerpt of the developed factors, broken down into their component categories. The entire list of factors is shown in Appendix A.

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Table 3. Excerpt of the Final List of Readiness Factors

1. Project Team Factors
1. Have the project goals been defined?
2. Have the project drivers (cost/schedule) been agreed on by the team?
3. Have the goals and objectives been documented?
4. Has the team communicated project goals among themselves?
5. Has the (Responsible, Accountable, Consulted and Informed) RACI matrix been developed for the project?
6. Has an organizational chart been developed to assign roles and functions?
7. Has the organizational chart been distributed and communicated to all pertinent parties?
8. Are all key project team leadership positions filled?
9. Have proven leaders been assigned to the project?
10. Is a support system in place to allocate resources?
11. Is the frequency of project team meetings (e.g., daily, weekly, or monthly) defined?
12. Are the required intervals of reports of the project team (e.g., daily, weekly, or monthly) defined?
13. Was the project team formed in a timely manner?
14. Do the project team members have all required skills?
15. Do all project team members have the capacity (e.g., availability, experience) to take on the project?
16. Have the project team members received training regarding project-specific procedures?
17. Is there a system for managing cultural diversity (no social/political impediments among team members)?
18. Has a system of oversight and governance been established for the project?
19. Does the project team include representative(s) from the engineering team?
20. Does the project team include representative(s) from the procurement team?
21. Does the project team include representative(s) from the fabrication team?
22. Does the project team include representative(s) from the construction team?
23. Does the project team include representative(s) from the sub-contractor team?
24. Does the project team include representative(s) from the owner team?
2. Engineering Factors
1. Have all engineering milestones been developed?
2. Have all engineering deliverables in construction packages been defined?
3. Are standards and specifications needed to support construction clearly published?
4. Have (issued-for-construction) IFC drawings been issued to the point that supports construction activity?
5. Is the schedule for design deliverables compatible with the sequence of construction?
6. Have clash and interference checks been completed?
7. Is there a procedure for the timely implementation of receiving vendor information?
8. Have commissioning and startup requirements been incorporated in the design?
9. Have discipline design interfaces been well coordinated?
10. Have engineering responsibilities been clearly defined?
11. Has operability been incorporated in design?
12. Is there a defined process for responding to RFIs in a timely manner?
13. Is the submittal process defined?
14. Is the process for approval of shop drawings clear?
15. Is the process for updating drawings defined?
16. Is the process for reporting RFIs impacting schedule and cost clear?
17. Is there a defined system of engineering support (including planned on-site availability)?
Note: the entire table is presented in Appendix A

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3.3 Summary

RT-DCC-02, through the process enumerated in this chapter, sought to develop a comprehensive list of factors that differentiate CR and CNR projects. IT used the Kawakita Jiro method to sift the factors identified from literature, the CII Knowledge Base, industry experience, and existing industry practice into a final list of 228 factors. These factors can apply to virtually every type of construction project, and they form the basis of the quantitative scoring system and a delineation between CR and CNR projects, which will be discussed in forthcoming factors.

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Chapter 4:
Data Collection and Overview

While the factors developed and discussed in Chapter 3 provide a qualitative method of assessing construction readiness, a quantitative method was also needed to develop the weights of the factors and highlight the most significant factors that differentiate Construction-Ready (CR) projects from Construction-Not-Ready (CNR) projects. As such, the research team developed a project-based survey to collect extensive data from both CR and CNR projects. These terms are defined as follows:

- **CR Project** – a project that was construction-ready at the time of starting construction. CR projects normally commence and sustain construction activities in a productive manner by completing all necessary preconstruction activities.
- **CNR Project** – a project that prematurely commenced construction. CNR projects normally have frequent stop-and-go work, and/or the work is not constructed in the most efficient manner, which can negatively affect time, schedule, and other performance metrics.

By analyzing the data gathered through this survey, the research team was able to:

- Weight the construction readiness factors and highlight the ones which were most significant in differentiating CR from CNR projects,
- Develop a Project Construction Readiness score that can be used to assess the readiness level of a project as a percentage,
- Benchmark the Project Construction Readiness Score to differentiate between Construction-Ready (CR), Borderline, and Construction-Not-Ready (CNR) projects, and
- Analyze and quantify the performance differences between CR and CNR projects.

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4.1 Survey Development

During the process of developing the final list of factors, each factor was rephrased such that it was answerable as a binary question (i.e., yes or no). The team then expanded this list of questions, adding sections that gathered data related to project features (e.g., location or size) and project performance. These additional sections allowed all projects to be compared as part of one dataset. This first draft of the survey was then reviewed internally and by a pilot group (the industry members of the team) using data from projects executed by their companies. This pilot group provided 10 data points, which were analyzed to ensure the data collected by the survey aligned

with the research objectives. In addition, the pilot group tested the ease of use and clarity of the survey to ensure other respondents would have the easiest time possible completing it. As is the nature of a development process, some questions were removed, edited, or clarified, but the survey remained largely the same throughout. After the pilot period concluded, the survey was loaded into a digital distribution platform (Qualtrics) for the widespread launch.

The final survey was broken down into the following four sections:

1. **General Information** – This section contained 17 questions that collected data related to project features and characteristics, such as the project's delivery system, location, and whether the project was CR or CNR.
2. **Readiness Factors** – This section's 228 questions related to the readiness factors: 15 categories that are explained in Chapter 3.
3. **Performance Indicators** – This section focused on project performance, asking 22 questions whose responses could be used to compute 14 performance metrics spanning seven performance areas, such as cost, schedule, and quality.
4. **Survey Feedback** – This section used five questions to gather data about the respondents' feedback about the survey; particularly the wording of the readiness factors.

In total, the survey gathered 264 variables from each respondent project.

4.2 Data Overview

In order to ensure an adequate sample size, the revised project-based survey was disseminated to all corporate members of the Construction Industry Institute (CII), as well as other project professionals who showed interest in the research topic. In total, 181 professionals were contacted to participate in the survey's data collection efforts. Overall, RT-DCC-02 successfully gathered data from 80 projects.

4.2.1 Readiness Status

It was essential that the distribution of CR and CNR projects was close to even so that the analysis of differentiating factors could be performed, as well as comparing CR to CNR projects. Fortunately, this was achieved, as can be seen in Figure 5.

4.2.2 Geographic Distribution

The survey was not designed to include a geographic preference for respondent data. As a result, 71 projects were located in North America, five in South America, three in the Middle East, and one in Asia. Within North America, projects were located in 21 U.S. States as well as Canada and Mexico. Figure 6 presents the geographic location of studied projects within the U.S. (highlighted states had at least one respondent project).

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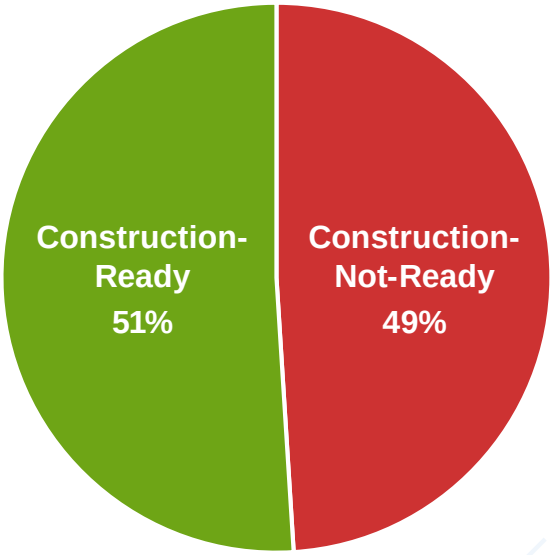

Figure 5. Readiness Status of Studied Projects

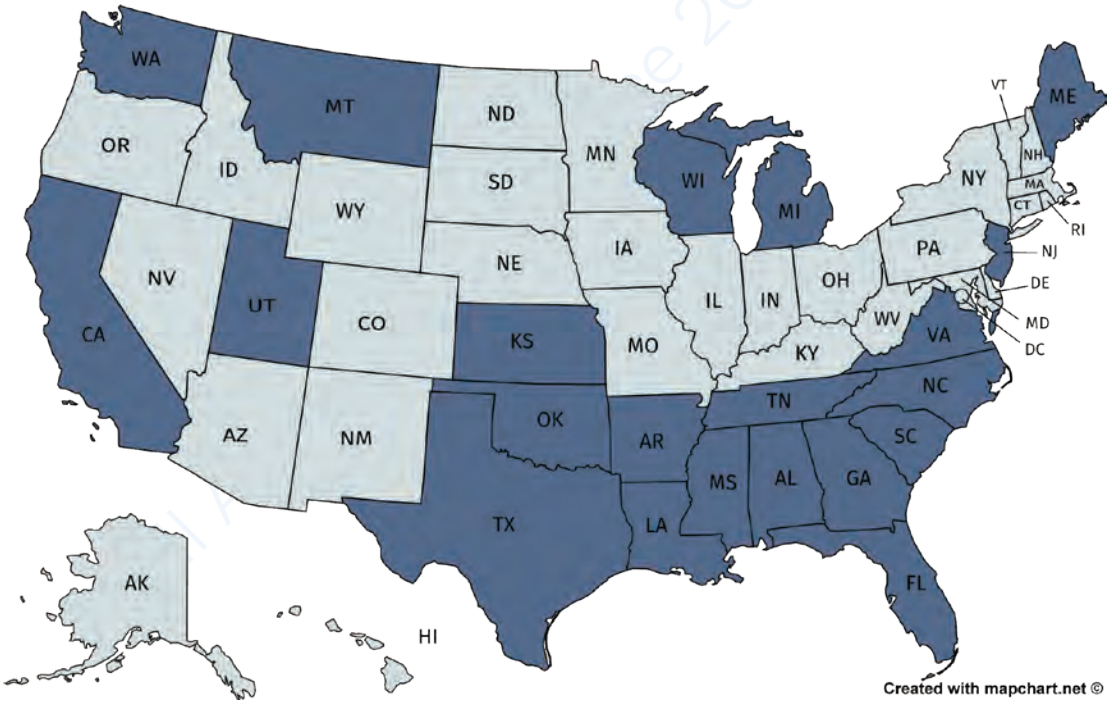

Figure 6. Geographic Distribution of Studied Projects Located in the U.S.

4.2.3 Respondents' Project Role

In order to ensure a comprehensive perspective, the survey was disseminated to both owners and service providers, which comprise: General Contractors or Construction Managers (GC/CM), Engineering Procurement and Construction (EPC), Engineering Procurement Construction and Management (EPCM), and others, such as subcontractors and vendors. Figure 7 depicts the distribution of the respondent's roles in the studied projects.

4.2.4 Industry Sector

The majority of the responses (66%) came from the Downstream and chemicals sector of the construction industry. This is logical, given the umbrella under which this study was funded and the makeup of its participants. However, to ensure intersectional compatibility other sectors were included as well, amounting to 33% of respondents. This 33% can be further broken down into Power, Utilities, and Infrastructure (PUI), Upstream, Midstream, and Mining (UMM), Facilities and Healthcare (FH), and Manufacturing and Life Sciences (MLS). A full breakdown is depicted in Figure 8.

4.2.5 Owner Type

The majority of respondents were privately owned, but some publicly owned projects were also included, as shown in Figure 9.

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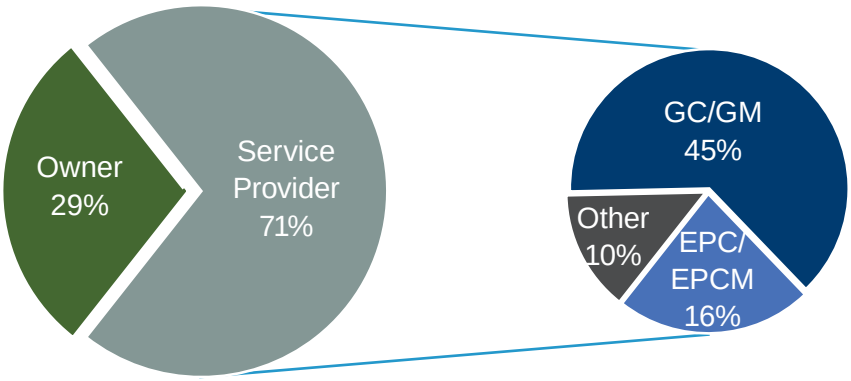

Figure 7. Respondents' Roles in Studied Projects

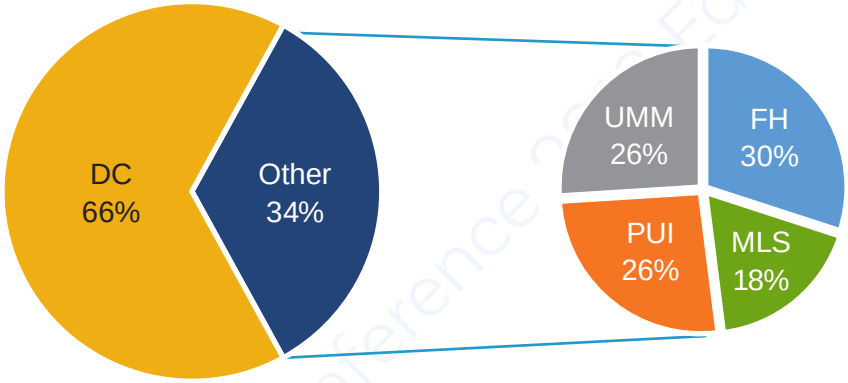

Figure 8. Industry Sectors of Studied Projects

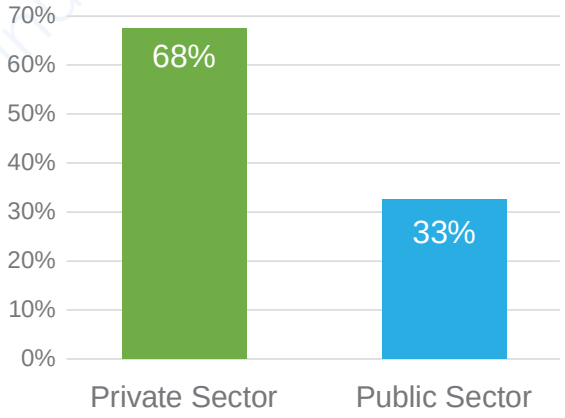

Figure 9. Owner Types of Studied Projects

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4.2.6 Project Delivery System

No single delivery system was used on the majority of projects studied. The most common delivery system was Design-Bid-Build (DBB), which was used on 23% of projects. However, a substantial number of respondents used Design-Build (DB), Integrated Project Delivery (IPD), Construction Manager Agent or At Risk (Agent or CMR), or other delivery systems. Respondents were presented with the option to fill in a delivery system that was not listed on the survey under the “other” field. These responses included EPC, EPCM and EPCF (Engineering, Procurement, Construction and Fabrication). The full breakdown of delivery systems is shown in Figure 10.

4.2.7 Contract Type

The survey included almost every major contract type that is commonly used in modern construction. The most common response was a lump-sum contract (36% of respondents). Time and Materials and Cost-Plus Fee were two other common responses, and Guaranteed Maximum Price and Unit Price were less common but present as well. The distribution of contract types is shown in Figure 11.

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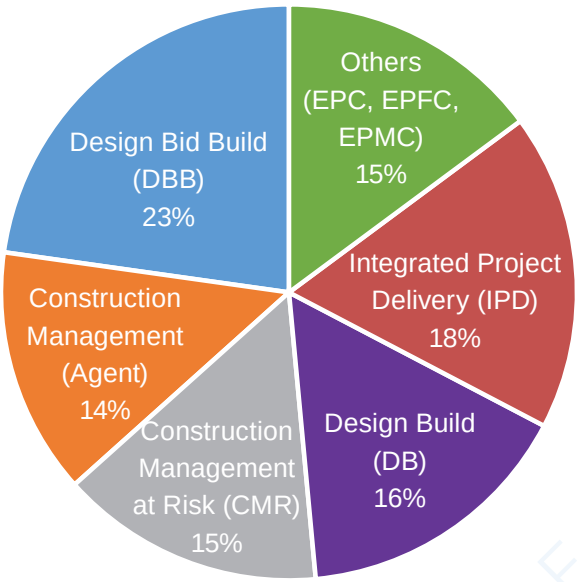

Figure 10. Project Delivery Systems of Studied Projects

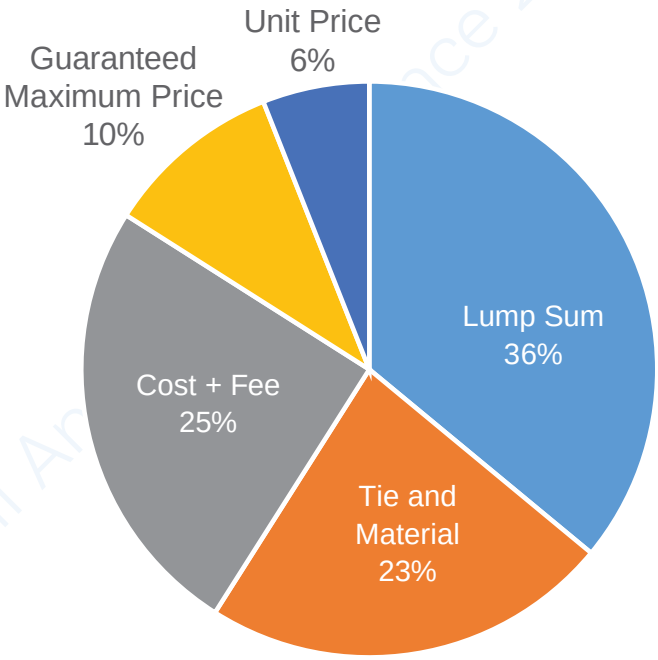

Figure 11. Contract Types of Studied Projects

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4.2.8 Construction Pace

Within this study, construction pace refers to either the use of a fast-track approach or not. While no preference for fast-track construction was expressed, most respondent projects did use a fast-track approach, as is shown in Figure 12. However, a sufficient number of respondents used traditional construction pacing, allowing this research to apply to that pace as well.

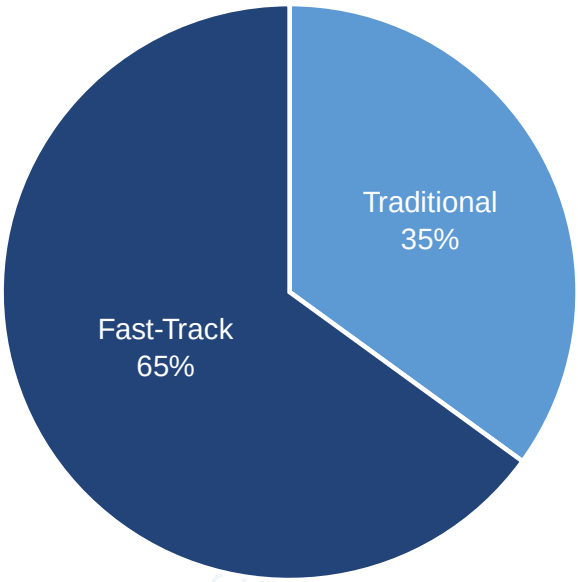

Figure 12. Construction Pace of Studied Projects

4.2.9 Construction Cost

In total, about $20 billion of construction was examined in this study. On average, respondent projects cost about $285 million. The most common value for studied projects was between $100 million and $500 million. A full distribution of construction costs is shown in Figure 13.

4.2.10 Construction Duration

In total, the projects studied in this research had a construction duration of over 5300 weeks or 102 years. On average, respondent projects' construction duration was 83 weeks. The most common range of duration was 50 to 100 weeks. A full distribution of the construction duration of studied projects is shown in Figure 14.

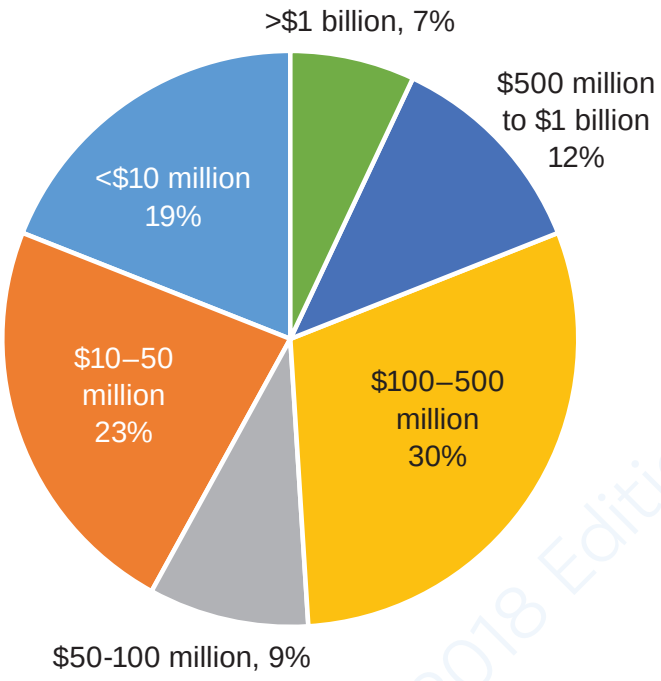

Figure 13. Construction Cost of Studied Projects

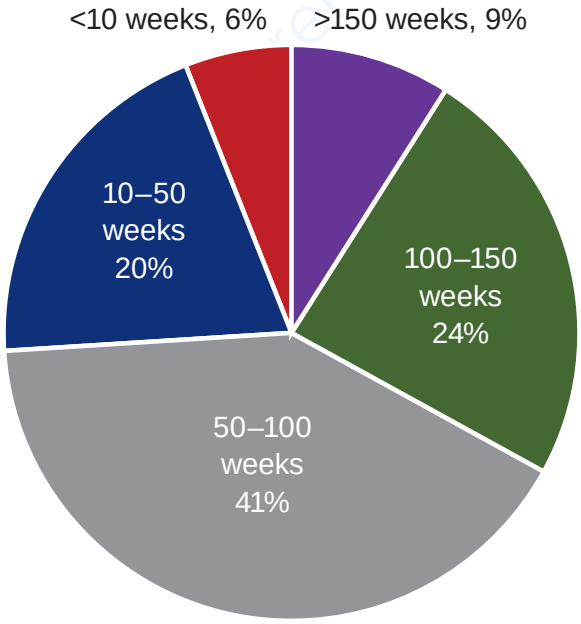

Figure 14. Construction Duration of Studied Projects

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4.2.11 Project Completeness

Most projects in the dataset were recently completed at the time the survey was taken, however a portion of them were still ongoing. This distribution is shown in Figure 15.

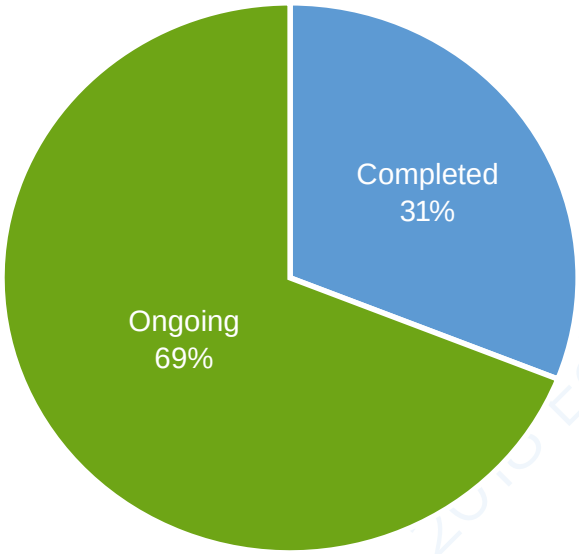

Figure 15. Project Completeness of Studied Projects

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Chapter 5:
Data-driven Findings

The survey discussed in Chapter 4 provided an extensive amount of data. The research team analyzed this data to draw data-driven conclusions within four principal objectives. These objectives were:

1. Derive weights for each readiness factor and in so doing highlight those factors that are the most significant in differentiating Construction-Ready (CR) projects from Construction-Not-Ready (CNR) ones.
2. Use the weights to help develop a Construction Readiness Score (CRS) which can be used to assess a projects readiness across all the defined factors as a single percentage.
3. Analyze CRS of the sample projects to define benchmarks and separate projects into CR, Borderline, or CNR.
4. Quantify the difference in performance between CR and CNR projects to underscore the importance of being CR before proceeding.

The remainder of this chapter is structured into four subsections that mirror the four objectives above.

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5.1 Weighting Readiness Factors

In order to determine the relative importance of each of the 228 factors, the team developed a data-driven mathematical model using the data collected by the survey. The model was designed to highlight which factors tend to distinguish CR from CNR projects. To this end, let y be the project construction readiness status. In this sense, $y = 0$ if the project is CNR, and $y = 1$ if the project is CR. Also, for each $1 \leq i \leq 228$, let x_i denote the project's rating for readiness factor i.

In this sense, x_i is either 0 (indicating that the factor was missed by the project) or 1 (indicating that the factor was implemented in the project). For each pair of projects m and n,

$$s_i = \sum_{m \neq n} (y_m - y_n)(x_{i_m} - x_{i_n})$$

where s_i is the weighting score of a readiness factor that can be used to derive the weight of factor i (w_i) using the following equation:

$$w_i = \frac{s_i}{\sum_{i=1}^{228} s_i}$$

so that:

$$\sum_{i=1}^{228} w_i = 1$$

5.1.1 Key and Fundamental Factors

During the process of computing the weights it was found that of the 228 identified factors, 210 were “key” factors, while 18 were “fundamental” factors. What differentiates key from fundamental factors in this instance is that a key factor is one that is performed by a high percentage of CR projects but is missed by a high percentage of CNR projects. Thus, key factors are better differentiators of CR and CNR projects than fundamental factors. An example of a key factor from this research is performing clash detection analysis. That is not to say, however, that fundamental factors are unimportant. Rather, they are actions or tasks that are so integral to the process of construction that both CR and CNR projects performed them consistently – all of the projects in the dataset performed each of the 18 fundamental factors.

An example of a fundamental factor is having a safety plan in place for the job. But, it should be noted that not performing a fundamental factor would certainly not aid in being construction-ready. As such, the fundamental factors were included in the final list, as they should still be considered, but were excluded from the weighting process as they did not effectively contribute to differentiating CR from CNR projects.

5.1.2 Clustered Table of Ranked Factors

Table 4 presents an excerpt of the 228 readiness factors, sorted by their weights (highest weight at the top). Within this table, each factor has also been assigned a numeric code (e.g., 7.01). The first two digits indicate which category contains this factor. The second two digits do not denote rank within the category; rather, they refer back to that factor’s numbering within its category in Appendix A.

The numeric codes for categories are shown in Table 2 in Chapter 3. The third column of this table presents the weighted values as percentages. The higher the percentage, the more impactful that factor is in distinguishing CR from CNR. Higher percentage factors are consistently performed by CR projects and consistently missed by CNR projects. The sum value of the weights is 100% (i.e., if each factor is accounted for, a project is 100% CR). The rightmost column of this table shows which Importance Cluster a factor belongs to. By dividing the data into clusters, the team gained an understanding about which group(s) of factors are most impactful on a project’s readiness.

Cluster analysis is a statistical method to group data by comparing each candidate factor to each other factor already in the group. If the difference between the candidate factor and the other factors already in the cluster is significant, then the candidate factor is assigned to a different cluster. In this report, the most important factor is Importance Cluster 1, followed by those factors in Clusters 2, 3, and so on. The entire clustered table of ranked readiness factors is shown in Appendix B.

Table 4. Excerpt of the Clustered Table of Ranked Readiness Factors, Clusters 1–3

Factors	Weight	Cluster
2.04. Have (issued-for-construction) IFC drawings been issued to the point that supports construction activity?	1.848%	1
3.12. Are the labor productivity rates for major items in line with recent experiences?	1.244%	Cluster 2
2.05. Is the schedule for design deliverables compatible with the sequence of construction?	1.230%	
1.20. Does the project team include representative(s) from the procurement team?	1.174%	
2.16. Is the process for reporting RFIs impacting schedule and cost clear?	1.166%	
3.18. Have all the hold points/handoffs been identified?	1.166%	
3.11. Are planned activities durations in line with project conditions?	1.164%	
15.03. Is there a process in place for responding to delay?	1.164%	
14.02. Is there a system in place to align construction with commissioning and operations?	1.142%	
2.09. Have discipline design interfaces been well coordinated?	1.139%	
13.11. Are clear procurement process and supporting systems in place for storage?	1.126%	
14.01. Are procedures for turnover (from construction to commissioning) well-defined?	1.073%	
8.13. Is there a shared understanding of the change management process among the project team?	1.041%	Cluster 3
5.01. Are the relevant contracts signed to support construction schedule?	1.021%	
8.10. Is there a defined process to reconcile change orders to scope?	0.970%	
3.15. Are the requirements of different stakeholders considered in the planning process?	0.966%	
1.15. Do all project team members have the capacity (e.g., availability, experience) to take on the project?	0.963%	
8.07. Is there a procedure for the update of all documents affected by changes?	0.963%	
1.19. Does the project team include representative(s) from the engineering team?	0.960%	
5.11. Is there adequate vertical transportation (e.g., cranes, elevators)?	0.956%	
8.15. Is there a process for documenting rework activities?	0.946%	
3.19. Have all the hold points and handoffs been integrated in the schedule?	0.933%	
1.21. Does the project team include representative(s) from the fabrication team?	0.902%	
2.07. Is there a procedure for the timely implementation of receiving vendor information?	0.890%	
3.23. Has the project testing plan been incorporated in the schedule?	0.878%	
2.02. Have all engineering deliverables in construction packages been defined?	0.875%	
15.05. Is there a process in place to monitor and control productivity?	0.875%	
Note: the entire table is presented in Appendix B		

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It should be noted that of the factors that ranked in the top two clusters, the most frequently occurring category was Engineering (four factors), followed by Planning (three factors), and Commissioning (two factors). Also represented in these clusters were Project Team, Procurement and Material Management, and Project Controls.

This distribution is logical because elements of these categories must be in place in order to be construction-ready. However, the number of highly weighted factors that were categorized into Engineering indicate the cruciality of a strong level of engineering involvement pre-construction.

5.1.3 Ranking within Categories

Appendix C presents each category individually, with the factors that comprise it ranked in order of weight within that category only. The highest weighted factor in each category is shown in boldface. This presentation shows which are the leverage factors in a given category, indicating to practitioners which factors should be targeted for improvement. In this sense, the within-category rankings prioritize the most effective order in which to address the factors of a given category, while the overall rankings prioritize the most effective order in which to address the factors as a whole. Table 5 provides an excerpt of the readiness factors ranked within categories.

Table 5. Excerpt of the Readiness Factors Ranked within Categories

Factor Code	Factors	Cluster
	Category 1: Project Team	
1.20	**Does the project team include representative(s) from the procurement team?**	**Cluster 2**
1.15	Do all project team members have the capacity (e.g., availability, experience) to take on the project?	Cluster 3
1.19	Does the project team include representative(s) from the engineering team?	Cluster 3
1.21	Does the project team include representative(s) from the fabrication team?	Cluster 3
1.02	Have the project drivers (cost/schedule) been agreed on by the team?	Cluster 4
1.24	Does the project team include representative(s) from the owner team?	Cluster 5
1.11	Is the frequency of project team meetings (e.g., daily, weekly, or monthly) defined?	Cluster 5
1.23	Does the project team include representative(s) from the sub-contractor team?	Cluster 5
1.14	Do the project team members have all required skills?	Cluster 6
1.16	Have the project team members received training regarding project-specific procedures?	Cluster 6
1.03	Have the goals and objectives been documented?	Cluster 6
1.04	Has the team communicated project goals among themselves?	Cluster 6

Factor Code	Factors	Cluster
1.22	Does the project team include representative(s) from the construction team?	Cluster 6
1.09	Have proven leaders been assigned to the project?	Cluster 7
1.18	Has a system of oversight and governance been established for the project?	Cluster 8
1.07	Has the organizational chart been distributed and communicated to all pertinent parties?	Cluster 9
1.13	Has the project team been formed in a timely manner?	Cluster 9
1.17	Is there a system for managing cultural diversity (no social/political impediments among team members)?	Cluster 9
1.01	Have the project goals been defined?	Cluster 10
1.06	Has an organizational chart been developed to assign roles and functions?	Cluster 10
1.08	Are all key project team leadership positions filled?	Cluster 10
1.05	Has the (Responsible, Accountable, Consulted and Informed) RACI matrix been developed for the project?	Cluster 10
1.12	Are the required intervals of reports of the project team (e.g., daily, weekly, or monthly) defined?	Cluster 10
1.10	Is a support system in place to allocate resources?	Fundamental
Category 2: Engineering		
2.04	**Have (issued-for-construction) IFC drawings been issued to the point that supports construction activity?**	**Cluster 1**
02.05	Is the schedule for design deliverables compatible with the sequence of construction?	Cluster 2
02.16	Is the process for reporting RFIs impacting schedule and cost clear?	Cluster 2
02.09	Have discipline design interfaces been well coordinated?	Cluster 2
02.07	Is there a procedure for the timely implementation of receiving vendor information?	Cluster 3
02.02	Have all engineering deliverables in construction packages been defined?	Cluster 3
02.03	Are standards and specifications needed to support construction clearly published?	Cluster 4
02.10	Have engineering responsibilities been clearly defined?	Cluster 4
02.08	Have commissioning and startup requirements been incorporated in the design?	Cluster 5
02.14	Is the process for approval of shop drawings clear?	Cluster 5
02.15	Is the process for updating drawings defined?	Cluster 5
02.17	Is there a defined system of engineering support (including planned on-site availability)?	Cluster 5
02.01	Have all engineering milestones been developed?	Cluster 5
02.06	Have clash and interference checks been completed?	Cluster 5
02.13	Is the submittal process defined?	Cluster 7
02.12	Is there a defined process for responding to RFIs in a timely manner?	Cluster 8
02.11	Has operability been incorporated in design?	Cluster 8
Note: the complete table is presented in Appendix C		

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5.2 Construction Readiness Score

The second section of this chapter discusses the CRS. The CRS score uses the derived weights discussed previously to quantitatively assess a project's overall readiness. This score is designed to distill the copious number of factors into a single value, in this case a percentage. The formulation of the score, as well as the scores of the projects in the study are discussed in this section.

5.2.1 Mathematical Formulation

The mathematical score of a project is calculated in the following manner:

(Factor 1 Performance Multiplier × Factor 1 Weight)
+ (Factor 2 Performance Multiplier × Factor 2 Weight)
+ (Factor 3 Performance Multiplier × Factor 3 Weight) + . . .
+ (Factor 228 Performance Multiplier × Factor 228 Weight)

In this equation, the performance multiplier takes the value of either 1 or 0, depending on if a factor was or was not performed, respectively. The weight is the decimal value of the percentages expressed previously. When the calculation is performed, the result is a decimal value that equates to a percentage between 0% and 100%. The higher the value, the more construction-ready the project.

However, it should be noted that some factors may not apply to all projects. In that case, the non-applicable factor is omitted from the calculation as it is neither not performed, nor performed. Rather, that factor's weight is redistributed across the remaining factors in such a fashion as to preserve the existing clusters and differences.

5.3 Construction Readiness Benchmarks

The equation prescribed in the previous section was used to calculate the CRS of each of the projects in the dataset. Once the scores were tabulated, the team sought to define a benchmark to separate CR projects from CNR projects. This section elaborates on and discusses this process, and presents the final classifications.

5.3.1 Classifying CR vs. CNR

Initially, the team plotted the scores of CR and CNR projects as boxplots, and drew a cutoff line between them as the benchmark for a CR project. This value was a CRS of 80%, as shown in Figure 16.

However, there were some projects that were previously classified as CR that this benchmark would classify as CNR, and vice versa. The team also found it illogical that

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a project that was not CR with a score of 79.9% would suddenly be rendered CR by a score increase of only 0.1%. Clearly, there had to exist some sort of transitional zone. Therefore, the decision was made to define a third category: Borderline. A borderline project is nearly CR, but not quite. More preparations should be made to ensure that the project's score enters the CR range before proceeding. As shown in Figure 17, the borderline range falls between CRS of 75% and 85%, thus more logically classifying projects and reducing misclassification.

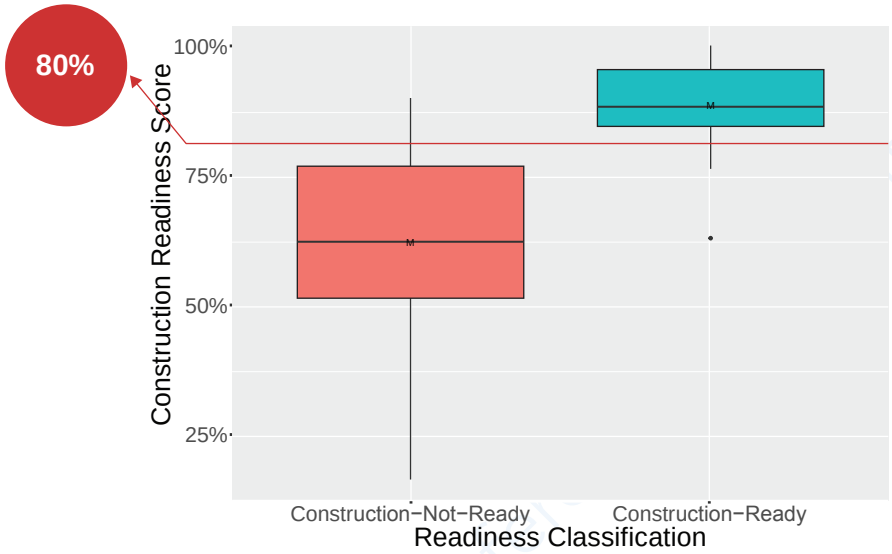

Figure 16. Cutoff CRS Score between CNR and CR Projects

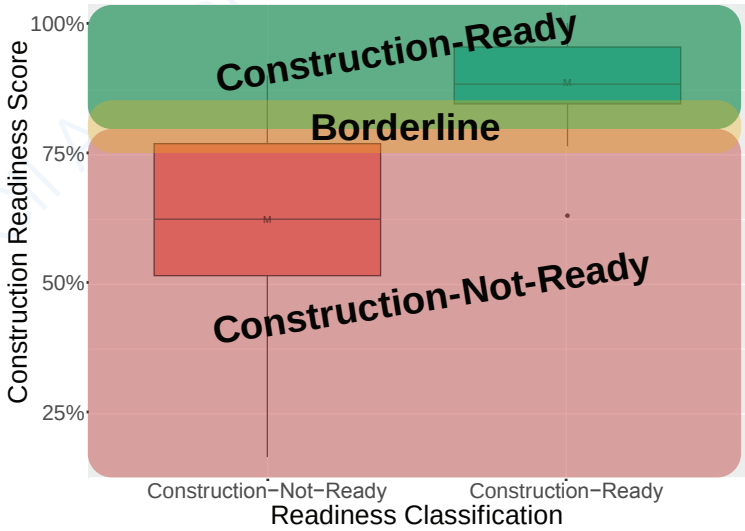

Figure 17. Cutoff CRS Scores between CNR, Borderline, and CR Projects

5.3.2 Stability of the Model

The model was tested three times during development, and then validated after it was finalized to ensure stability. The first test was conducted on the first 26 projects that reported data. The second test was conducted on the first 57 projects to report data. The final test was conducted on all 80 reporting projects. As the sample size increased, the cutoff scores tended to converge, as shown in Table 6.

Table 6. Convergence of CRS Cutoff Scores

Number of Studied Projects	CRS Range of CNR Projects	CRS Range of Borderline Projects	CRS Range of CR Projects
26	[0%,56%)	[56%,87%)	[87%,100%]
57	[0%,73%)	[73%,86%)	[73%,86%]
80	[0%,75%)	[75%,85%)	[75%,85%]

Additionally, and as will be further discussed in Chapter 7, 10 new projects submitted data that was used to validate the model. The thresholds once again held true, proving the model stable and ready to use.

5.4 Impact of Readiness on Project Performance

The fourth objective of the data-driven analysis was to statistically analyze the performance differences between CR and CNR projects. To do so, using the survey data, CR and CNR projects were plotted against each other in box plots for each performance metric. The difference between them was then assessed using statistical tests for significance. Those differences which were found to be significant were then quantified. The following subsections detail each performance metric, and the degree to which CR projects outperformed CNR projects.

5.4.1 Statistical Methodology

The first step in statistically investigating the impact of construction readiness status was the use of exploratory and descriptive statistical methods. These methods were used to help set the benchmarks for CR and CNR projects. For each studied performance metric, comparative box-and-whisker plots were developed. In these plots, the x-axis represents the project's construction readiness status and the y-axis represents the studied performance metric. In addition to the customarily illustrated first, second, and third quartiles, the mean/average was also denoted by the letter "M." These labels are further explained in Figure 18.

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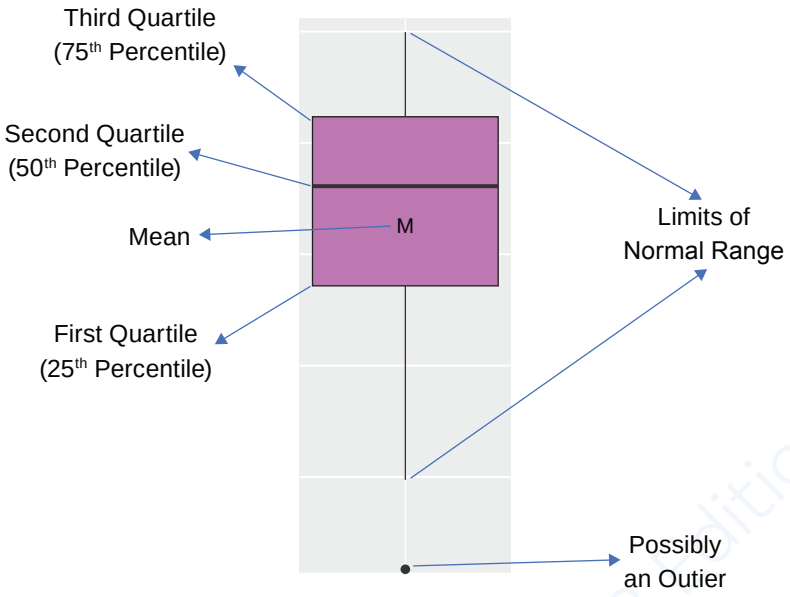

Figure 18. Illustration of the Box-and-Whisker Plot Used

The second step was to test assumptions of normality and homoscedasticity, to determine which statistical tests would best suit the data. The primary mechanism of the testing was the Wilcoxon Rank-Sum test, which was used to determine if the performance metric being studied significantly differed between CNR and CR projects. This test returns a p-value, which expresses the probability that the null hypothesis is correct. The smaller the returned p-value, the stronger the statistical evidence that the performance metric being studied significantly differed between CR and CNR projects. It this research study, p-values less than 0.05 were used to report statistically significant results at a 95% confidence level.

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5.4.2 Cost Performance

Cost performance, as used here, is comprised of two metrics: Construction Cost Growth and Project Budget Factor. Construction Cost Growth is calculated using the following equation:

$$\text{Construction Cost Growth} = \frac{\text{Actual Construction Cost} - \text{Initial Construction Cost}}{\text{Initial Construction Cost}} \times 100\%$$

Project Budget Factor is calculated using the following equation:

$$\text{Project Budget Factor} = \frac{\text{Actual Construction Cost}}{\text{Initial Construction Cost} + \text{Approved Changes}}$$

Figure 19 shows the boxplots for Construction Readiness Status vs. Construction Cost Growth and Project Budget Factor.

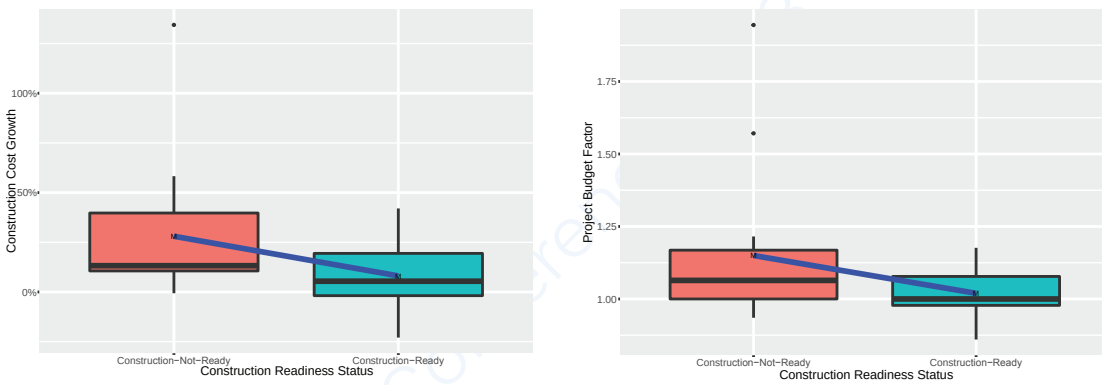

Figure 19. Construction Readiness Status vs. Cost Performance

The Wilcoxon Rank-Sum test was then used to determine if Construction Cost Growth and Project Budget Factor significantly differed between CNR and CR projects. The results of this test were as follows:

Table 7. Construction Readiness Status vs. Cost Performance

Performance Metric	P-Value	Result
Construction Cost Growth	0.005	Significantly different
Project Budget Factor	0.036	Significantly different

Thus, it was concluded that construction readiness significantly impacts performance in terms of both Cost Performance Metrics at 95% confidence level.

Since significance was found, the performance difference was quantified. It was found that CR projects outperformed CNR projects, on average, by 20% in terms of Construction Cost Growth and by 12% in terms of Project Budget Factor.

5.4.3 Schedule Performance

Schedule performance, as used here, is comprised of two metrics: Construction Schedule Growth and Project Schedule Factor. Construction Schedule Growth is calculated using the following equation:

$$\text{Schedule Growth} = \frac{\text{Actual Construction Schedule} - \text{Initial Construction Schedule}}{\text{Initial Construction Schedule}} \times 100\%$$

Project Schedule Factor is calculated using the following equation:

$$\text{Project Schedule Factor} = \frac{\text{Actual Construction Duration}}{\text{Initial Estimated Duration} + \text{Approved Changes}}$$

Figures 20 shows the boxplots for Construction Readiness Status vs. Construction Schedule Growth and Project Schedule Factor.

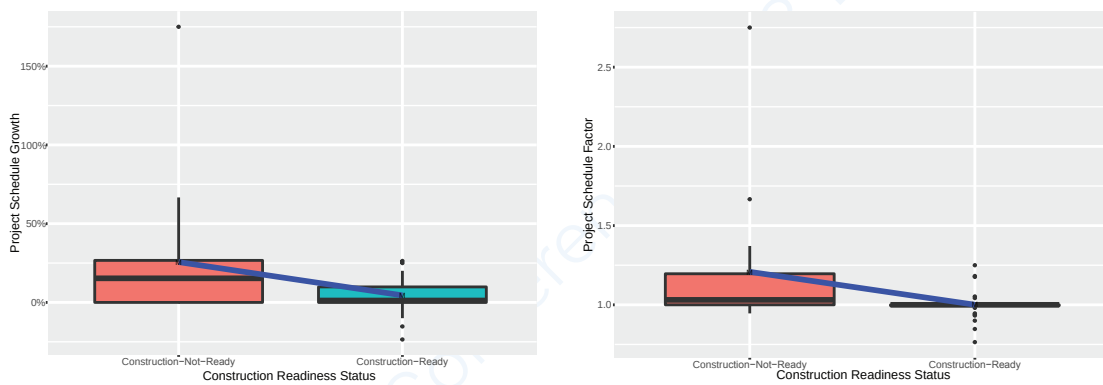

Figure 20. Construction Readiness Status vs. Schedule Performance

The Wilcoxon Rank-Sum test was then used to determine if Construction Schedule Growth and Project Schedule Factor significantly differed between CNR and CR projects. The results of this test were as follows:

Table 8. Construction Readiness Status vs. Schedule Performance

Performance Metric	P-Value	Result
Construction Schedule Growth	0.012	Significantly different
Project Schedule Factor	0.008	Significantly different

Thus, it was concluded that construction readiness significantly impacts performance in terms of both Schedule Performance Metrics at 95% confidence level.

Since significance was found, the performance difference was quantified. It was found that CR projects outperformed CNR projects, on average, by 21.5% in terms of Construction Schedule Growth and by 20.6% in terms of Project Schedule Factor.

5.4.4 Productivity Performance

Productivity performance, as used here, is comprised of two metrics: Performance Factor and Project Hours Factor. Performance Factor is calculated using the following equation:

$$\textit{Productivity Index} = \frac{\textit{Earned Project Hours}}{\textit{Actual Project Hours}}$$

Project Hours Factor is calculated using the following equation:

$$\textit{Project Hours Factor} = \frac{\textit{Actual Project Hours}}{\textit{Initial Estimated Hours + Approved Changes}}$$

Figures 21 shows the boxplots for Construction Readiness Status vs. Performance Factor and Project Hours Factor.

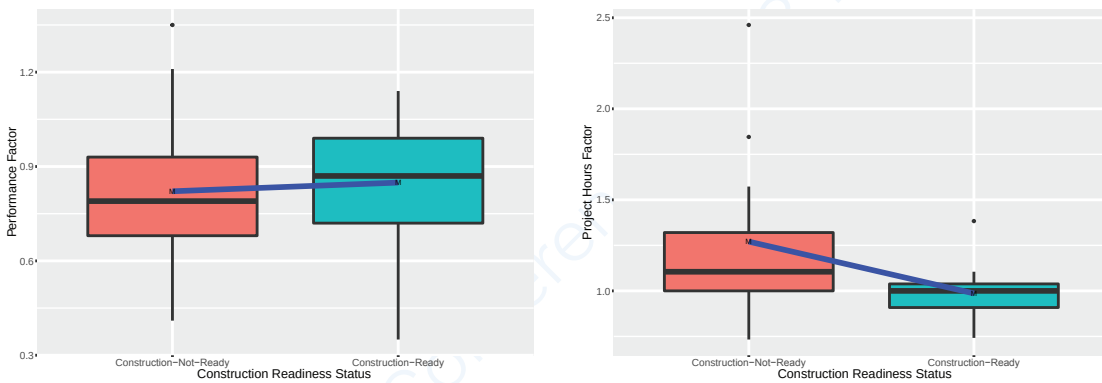

Figure 21. Construction Readiness Status vs. Productivity Performance

The Wilcoxon Rank-Sum test was then used to determine if Performance Factor and Project Hours Factor significantly differed between CNR and CR projects. The results of this test were as follows:

Table 9. Construction Readiness Status vs. Productivity Performance

Performance Metric	P-Value	Result
Performance Factor	0.707	Not significantly different
Project Hours Factor	0.016	Significantly different

Thus, it was concluded that CR significantly impacts performance in terms of the Project Hours Factor.

Since significance was found, the performance difference was quantified. It was found that CR projects outperformed CNR projects, on average, by 29% in terms of Project Hours Factor.

5.4.5 Quality Performance

Quality performance, as used here, is comprised of two metrics: Rework Percentage and Value of Punchlist Items. Rework Percentage is calculated using the following equation:

$$\textit{Rework Percentage} = \frac{\textit{Total Direct Cost of Field Rework}}{\textit{Actual Construction Cost}} \times 100\%$$

Value of Punchlist items is assessed qualitatively as: very low, low, moderate, high, or very high, relative to the industry average of similar projects.

Figures 22 shows the boxplots for Construction Readiness Status vs. Rework Percentage and Value of Punchlist Items.

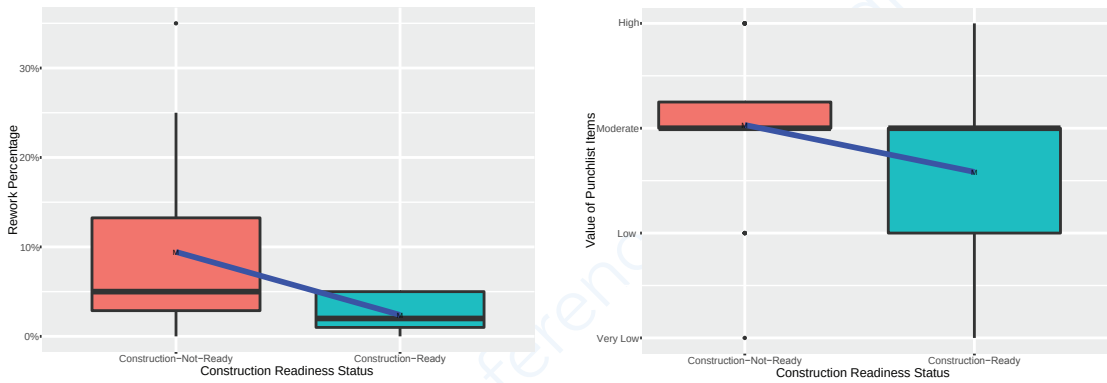

Figure 22. Construction Readiness Status vs. Quality Performance

The Wilcoxon Rank-Sum test was then used to determine if Rework Percentage and Value of Punchlist Items significantly differed between CNR and CR projects. The results of this test were as follows:

Table 10. Construction Readiness Status vs. Quality Performance

Performance Metric	P-Value	Result
Rework Percentages	0.001	Significantly different
Value of Punchlist Items	0.028	Significantly different

Thus, it was concluded that construction readiness significantly impacts performance in terms of both Quality Performance Metrics at 95% confidence level.

Since significance was found, the performance difference was quantified. It was found that CR projects outperformed CNR projects, on average, by 7% in terms of Rework Percentage.

5.4.6 Change Management Performance

Change management was studied in terms of the absolute value of the percent change. This is because changes that reduce project costs can be as disruptive as changes that increase project cost. Figures 23 shows the boxplots for Construction Readiness Status vs. Performance Factor and Project Hours Factor.

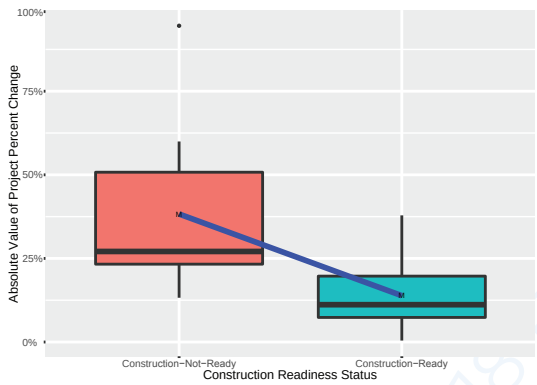

Figure 23. Construction Readiness Status vs. Project Percent Change

The Wilcoxon Rank-Sum test was then used to determine if Rework Percentage and Value of Punchlist Items significantly differed between CNR and CR projects. The results of this test were as follows:

Table 11. Construction Readiness Status vs. Project Percent Change

Performance Metric	P-Value	Result
Project Percent Change	0.000	Significantly different

Thus, it was concluded that construction readiness significantly impacts performance in terms of Project Percent Change at 95% confidence level.

Since significance was found, the performance difference was quantified. It was found that CR projects outperformed CNR projects, on average, by 21% in terms of Project Percent Percentage.

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5.4.7 Safety Performance

Safety performance, as used here, is comprised of two metrics: Occupational Safety and Health Administration (OSHA) Recordable Incident Rate and Lost-Time Injury (LTI) Rate. OSHA Recordable Incident Rate is calculated using the following equation:

$$\text{OSHA Recordable Incident Rate} = \frac{\text{Number of OSHA Recordable Cases} \times 200{,}000}{\text{Number of Labor Hours}}$$

LTI Rate is calculated using the following equation:

$$\text{LTI Rate} = \frac{\text{Number of Lost Time Cases} \times 200{,}000}{\text{Number of Labor Hours}}$$

Figures 24 shows the boxplots for Construction Readiness Status vs. OSHA Recordable Incident Rate and LTI Rate.

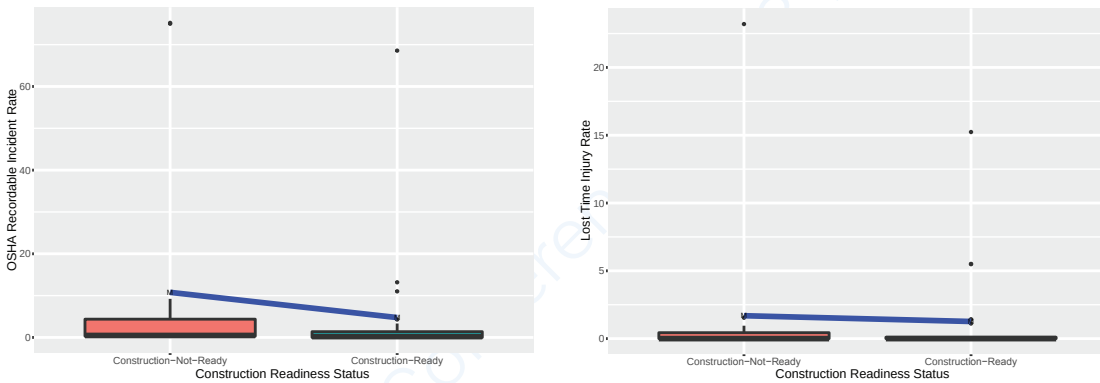

Figure 24. Construction Readiness Status vs. Safety Performance

The Wilcoxon Rank-Sum test was then used to determine if OSHA Recordable Incident Rate and LTI Rate significantly differed between CNR and CR projects. The results of this test are presented in Table 12.

Table 12. Construction Readiness Status vs. Safety Performance

Performance Metric	P-Value	Result
OSHA Recordable Incident Rate	0.122	Not significantly different
LTI Rate	0.761	Not significantly different

It is interesting but not altogether surprising that CR and CNR projects did not significantly differ in terms of safety performance. A high percentage of safety-associated readiness factors were deemed “fundamental” – i.e., they are performed routinely by all project types. This is demonstrative of an admirable industry-wide commitment to safety, which naturally begets safe projects, even if they are not construction-ready.

5.4.8 Communication Performance

Communication performance, as used here, comprises two metrics: Number of Request-For-Information forms (RFIs) per Million Dollars and RFI Processing Time. RFIs per Million Dollars, as calculated using the following equation:

$$\textit{RFIs per Million Dollars} = \frac{\textit{Number of RFIs} \times 1{,}000{,}000}{\textit{Construction Cost}}$$

RFI Processing Time is assessed in weeks. Figure 25 shows the boxplots for Construction Readiness Status vs. RFIs per Million Dollars and RFI Processing Time.

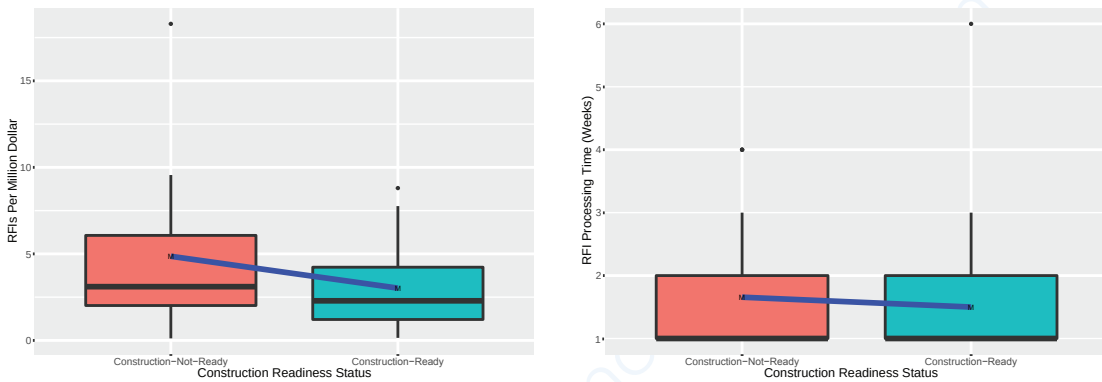

Figure 25. Construction Readiness Status vs. Communication Performance

The Wilcoxon Rank-Sum test was then used to determine if RFIs per Million Dollars and RFI Processing Time significantly differed between CNR and CR projects. The results of this test were as follows:

Table 13. Construction Readiness Status vs. Communication Performance

Performance Metric	P-Value	Result
RFIs per Million Dollars	0.344	Not significantly different
RFI Processing Time	0.376	Not significantly different

Thus, it was concluded that the studied communication performance metrics did not significantly differ between CR and CNR projects. The research team believes that this occurred for because the methods of communication measured (i.e., RFIs) are standard across both CR and CNR projects, and indeed across the construction industry. There is no more advanced method of communication that CR projects are using that could give them an advantage in this field. It is a known fact that communication is an issue in construction, and volumes of research have been published on the subject. From this statistical testing it is shown that being CR does not absolve a project of difficulties with RFIs, or communication in general.

5.4.9 Profitability Performance

Profitability performance was studied in this research in terms overhead and profit (O&P) percentage. O&P percentages was assessed as one of five categories: negative, 0 to 5%, 5-10%, 11-15%, or more than 15%.

Figure 26 shows the boxplot for Construction Readiness Status vs. O&H percentage.

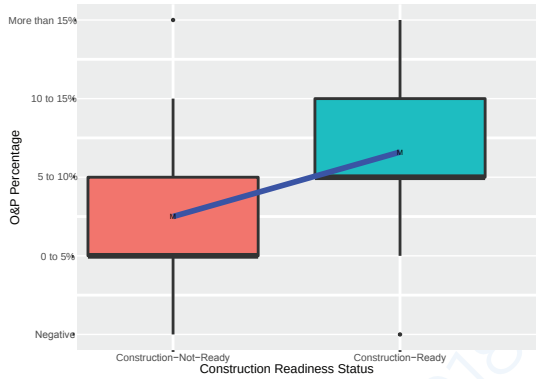

Figure 26. Construction Readiness Status vs. O&P Percentage

The Wilcoxon Rank-Sum test was then used to determine if O&P Percentage significantly differed between CNR and CR projects. The results of this test were as follows:

Table 14. Construction Readiness Status vs. Project Percent Change

Performance Metric	P-Value	Result
Project Percent Change	0.013	Significantly different

Thus, it was concluded that construction readiness significantly impacts performance in terms of O&P Percentage at 95% confidence level.

Since significance was found, the performance difference was quantified. It was found that CR projects outperformed CNR projects, on average, by around 3 to 5% in terms of O&P Percentage.

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Chapter 6:
Construction Readiness Assessment (CRA) Tool

To integrate the findings of the research into the workflow of industry professionals and to assist them in controlling construction readiness, the Construction Readiness Assessment (CRA) tool was developed. The CRA is built in Microsoft Excel-Visual Basic for Applications. The tool uses the weights of the 228 factors (as previously discussed in Chapter 5) to compute a unified project readiness score, and subsequently compares that score to both the benchmarks identified in this research and user-defined project goals. The CRA tool further identifies leverage areas in which improvement can be made to increase or maintain construction readiness. Repeated use of the tool during the planning and construction phases of a project permits projects to be tracked as they progress toward construction readiness and to ensure that readiness is maintained after startup.

6.1 Tool Procedure

There are two portions of the tool with which users will interact, as shown in Figure 27. The first is the Company-Level Options. When the tool is first run, it is in a state known as the "master file." Within this section, company executives may input specific company practices, company-specific factors that may not have been included in the research, may update target values for readiness to better align with company ideals to ensure the tool meets the needs of their company.

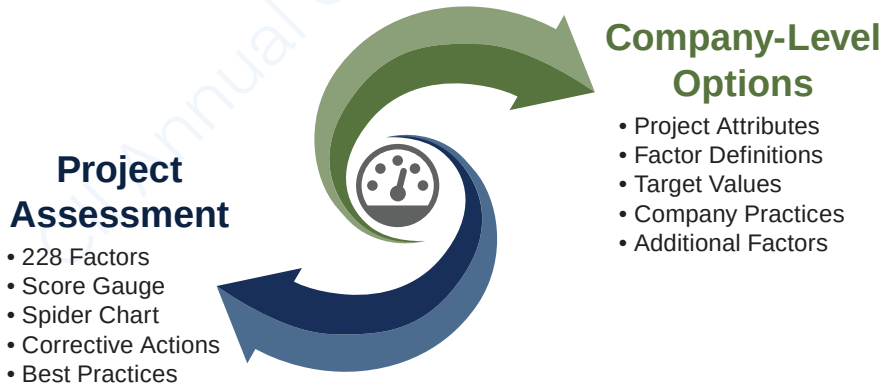

Figure 27. Levels of User Interaction

Once the master file has been customized satisfactorily, it is ready for use at the project level. Each time a project is assessed, a new file is created so that the master file is not altered in the process.

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6.1.1 Company-Level Options

Companies may customize the tool to fit their needs in five specific ways:

1. **Customizable tracked project attributes**: A company may add attributes to the project assessment tool in order to gather internal data about their projects over time. For example, a company could choose to add Project Delivery System as a tracked attribute, which would then be included in the assessment questions. The company will then have more specific, actionable data for internal analyses.
2. **Customizable Factor definitions and examples**: A company may provide specific examples and definitions for each of the 228 factors, using company-specific nomenclature or examples. These definitions will be populated into tooltips during the project-level assessment.
3. **Company-specific Target Values**: A company may add their own target values in each of the 15 readiness categories. These targets will then be compared to an examined project's score. This option tailors the tool's findings to better reflect the project readiness state based on the company's standards. If a company chooses not to customize these values, the default option (the average of the scores of studied construction-ready projects) is used.
4. **Specifying Company Practices**: By inputting the best practices currently in use, a company can ensure the tool provides targeted feedback in line with its own improvement efforts. Should a project score poorly in any of the 15 readiness categories, the tool returns the recommended company practice(s) to improve that category or categories.
5. **Inputting new factors**: The research team sought to make the tool as future-proof as possible. To that end, companies may edit the factor list to add new factors that may emerge in the future which have bearing on readiness. These factors could pertain to new technologies that were not previously available at the time of writing, or a new system of ideas that a company adopts. In either case, these factors will be reflected in the project assessment once added.

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6.1.2 Project Assessment

Once the company-level options have been specified, the project assessment module is ready. This is the main module of the tool. By creating a new project assessment file from the master file, an assessment is created that incorporates all company-level specifications and is automatically named for the project being studied.

Tool Inputs

There are two ways a user may answer the tool's data-gathering portion. The tool itself presents the 228 factors as yes or no questions (with an option to mark factors as not-applicable). A user may navigate through the tool to input project data. If it is easier

for a user to have all the factors in a single screen, the readiness assessment may be exported to a fillable excel sheet, then uploaded back into the tool for analysis.

If the user chooses to input the data natively through the tool, they are provided with informational tooltips containing either the definitions supplied by the research team or any specific company-level definitions prescribed. Regardless if the inputting method, any project attributes specified at the company-level portion of the tool will also be asked about. Also, within this section, the tool provides an opportunity for users to annotate the report that will be generated. An example annotation that the tool provides for is a list of the stakeholders who contributed to the assessment. For instance, if the project team is performing an early readiness check before certain key subcontractors are hired, they may note this to ensure it is recorded for later comparison.

Tool Outputs

The tool outputs the results of the assessment in several different forms. The user later has the option to select any or all of the results to be compiled into the printable report generated by the tool. Each of the returned results is designed to highlight a different aspect of the construction readiness assessment process. The output methods are as follows:

1. **Gauge**: The tool presents the projects overall CRS in the form of a gauge and plots it against the data-derived benchmarks that were discussed in Chapter 5. This visually communicates the readiness level of the project, as well as its readiness status (CR, borderline, or CNR).
2. **Spider chart**: The tool outputs a spider chart showing the project's category-specific scores in each of the 15 categories, plotted against either research-defined or company-defined targets. This makes it easy to understand which areas should be targeted for improvement. The information is also presented in a numerical, tabular, format to ensure that it is as understandable as possible.
3. **Action items**: Action items are identified based on any and all factors that the project team indicated they had not performed (i.e., those to which they answered "no"). In order to facilitate addressing the identified action items, the tool then helps the user build an action plan. The user may input project-specific actions they plan to take, identify person(s) who will be responsible for those actions, define a timeline to complete them, and make notes to clarify the precise steps that will be taken.
4. **Best practices**: Even if the user responds "yes" to factors within a category, that category's score may still be below the category's target value. The tool identifies any such categories and outputs targeted best practices to improve. The tool by default provides relevant CII best practices and, if the user inputs any company-specific practices for such categories, they will be returned at this stage.

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5. **Printing options**: At the conclusion of this process, a project-specific report is created. The user may also select any or all of the previous items to be contained in the report, with the choice of including the responses to the readiness factors (the input) or not. Also contained in the report are any notes the user inputs during the data collection phase.

6.1.3 Tracking Progress

As was touched on previously, a user may perform repeated assessments on the same project to track its progress. Each instance of analysis will be saved as a separate report (i.e., historical data is not overwritten to facilitate comparison). The tool includes a feature whereby users may compare the results of several trials by selecting those previously generated reports.

A user can go through as many readiness assessments for a certain project as needed, by creating new review for the same project. This is beneficial for users because a project can be assessed for construction readiness very early in the process; then again just before construction.

The tool tracks progress, and outputs the overall construction readiness scores of all reviews in a tabular format. Also, in the spider chart, the tool outputs the target values, actual scores as well as the scores from previous assessments. This allows the user to compare the project's progress against the target value over time.

6.2 Practical Application of the CRA Tool

RT-DCC-02 recommends that the tool be collaboratively used as ***early*** and ***often*** as possible, to provide the most actionable feedback while there is still ample time to address it prior to construction and to reap the benefit of ensuring team alignment on construction readiness. The tool is designed to assist teams achieve and maintain construction readiness for their projects. In many cases, the tool should be used multiple times to achieve its purpose. For example, the tool should be used early in the process to highlight leverage areas of improvement; then, the tool should be used again to ensure that the project has achieved readiness status and is ready to proceed to construction; afterwards, the tool should be used throughout the project to ensure sustaining the achieved readiness status. Also, using the tool collaboratively is key to exploiting its benefits. Project teams, including owners, contractors, engineers, subcontractors and vendors should use the tool together to ensure alignment and accuracy of the input data as well as the required action plan to achieve and maintain high readiness level. One model of using the tool that proved successful while beta-testing is having an independent facilitator leading the project team meetings of using the tool while ensuring fruitful discussions.

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Chapter 7:
Research Validation

The final step of the research was validating the tool and the findings that support it. The primary objective of the validation process was to assess the usability and functionality of the Construction Readiness Assessment (CRA) tool and to evaluate the accuracy of the classifications it produces. It was essential to validate the results of this research to ensure that the outputs of the tool are accurate, beneficial to users, and add value to the industry.

7.1 Further Data Collection and Overview

The method that the research team used to validate the findings was a secondary data collection and analysis. 10 projects not previously studied provided data. Nine were ongoing, while one was completed and participated retrospectively.

7.2 Model Validation

Prior to using the tool, the testers were asked to honestly and candidly assess the readiness status of their projects. This allowed the comparison of the tool's classification model with reality. 100% of the test projects were correctly classified based on the answer provided by the project's representative(s). 70% of the test projects were construction-not-ready, 10% were borderline, and 20% were construction-ready. This distribution was sufficient to validate the tool in all cases.

7.3 Tool Validation

Of course, the most accurate model in the world is useless if it is not user-friendly and valuable. The tool was validated by means of an exit survey.

Based on the survey responses, 100% of the testers reported that the tool was:

- Valuable in assessing construction readiness
- Valuable in enhancing construction readiness
- Has the potential to improve project performance
- User-friendly

More importantly, 100% of the testers reported that they plan to use the tool on their future projects.

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Chapter 8:
Conclusion and Future Research

In any major undertaking, being ready to proceed with construction is crucial. Prior to this research effort, there was no standard definition for construction readiness. Certainly, individual companies had internal definitions of what it meant to be construction-ready, but these lacked the comprehensiveness of a broader study. Furthermore, the body of literature that was extant prior to this research effort never concretely addressed solely construction readiness, instead assessing it alongside or subsidiary to other factors or concepts. In this sense, construction readiness was a present, but not fully understood concept.

This is unfortunate, because this study explicitly quantified the impact that being construction-ready can have on a project. It was found that Construction-Ready (CR) projects have on average 22% schedule reduction, 29% productivity improvement, 20% cost savings, 7% less rework, and 21% less change, relative to Construction-Not-Ready (CNR) projects. These are incredibly significant figures for an industry that historically has struggled with declining productivity and increasing costs.

To ensure that the industry can better prepare itself for construction readiness, 228 factors were identified. These factors were divided into fifteen holistic categories that cover elements of a project ranging from Project Team to Materials Management. The factors were then weighted. A higher-weighted factor was found to be performed by a high percentage of construction-ready projects but missed by a high percentage of construction-not-ready projects. Based on the weights developed, the Construction Readiness Score (CRS) was computed – a single, unified score that easily presents how construction-ready a project is.

In order to maximize the utility of this score, three thresholds of readiness were developed through a benchmarking process: Construction-Not-Ready (scores 0% < x < 75%), Borderline (scores 75 < x < 85), and Construction-Ready (scores 85% < x < 100%).

All of these findings and models were then incorporated into the Construction Readiness Assessment (CRA) Tool. The CRA tool allows a user to easily input their responses to each of the 228 defined factors. Based off the weights defined by this research, the overall CRS, as well as per-category scores for each of the fifteen categories are reported to the user, identifying leverage areas of improvement. To aid in this improvement, best practices are presented that apply to the leverage areas.

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The tool, furthermore, is highly customizable. A user may input new factors that apply more specifically to their company, or may provide the tool with internal best practices already in use to maintain consistent improvement efforts. The CRA, through repeated use, can also compare a project's evolution toward construction readiness during preparation, and further ensure that readiness is sustained during execution of the project.

While this research is comprehensive in its scope and provides a landmark in construction readiness literature, it would be arrogant to think that the landscape of construction will never change. Therefore, the authors recommend that the list of factors defined herein be revisited by future researchers, who may update them to include new technologies, practices, or problems in construction and may also remove factors that simply are no longer applicable on an industrial scale.

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Appendix A:
Final List of Construction Readiness Factors

1. Project Team Factors
1. Have the project goals been defined?
2. Have the project drivers (cost/schedule) been agreed on by the team?
3. Have the goals and objectives been documented?
4. Has the team communicated project goals among themselves?
5. Has the (Responsible, Accountable, Consulted and Informed) RACI matrix been developed for the project?
6. Has an organizational chart been developed to assign roles and functions?
7. Has the organizational chart been distributed and communicated to all pertinent parties?
8. Are all key project team leadership positions filled?
9. Have proven leaders been assigned to the project?
10. Is a support system in place to allocate resources?
11. Is the frequency of project team meetings (e.g., daily, weekly, or monthly) defined?
12. Are the required intervals of reports of the project team (e.g., daily, weekly, or monthly) defined?
13. Was the project team formed in a timely manner?
14. Do the project team members have all required skills?
15. Do all project team members have the capacity (e.g., availability, experience) to take on the project?
16. Have the project team members received training regarding project-specific procedures?
17. Is there a system for managing cultural diversity (no social/political impediments among team members)?
18. Has a system of oversight and governance been established for the project?
19. Does the project team include representative(s) from the engineering team?
20. Does the project team include representative(s) from the procurement team?
21. Does the project team include representative(s) from the fabrication team?
22. Does the project team include representative(s) from the construction team?
23. Does the project team include representative(s) from the sub-contractor team?
24. Does the project team include representative(s) from the owner team?
2. Engineering Factors
1. Have all engineering milestones been developed?
2. Have all engineering deliverables in construction packages been defined?
3. Are standards and specifications needed to support construction clearly published?
4. Have (issued-for-construction) IFC drawings been issued to the point that supports construction activity?
5. Is the schedule for design deliverables compatible with the sequence of construction?
6. Have clash and interference checks been completed?
7. Is there a procedure for the timely implementation of receiving vendor information?
8. Have commissioning and startup requirements been incorporated in the design?
9. Have discipline design interfaces been well coordinated?
10. Have engineering responsibilities been clearly defined?
11. Has operability been incorporated in design?
12. Is there a defined process for responding to RFIs in a timely manner?
13. Is the submittal process defined?
14. Is the process for approval of shop drawings clear?

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15. Is the process for updating drawings defined?
16. Is the process for reporting RFIs impacting schedule and cost clear?
17. Is there a defined system of engineering support (including planned on-site availability)?

3. Planning Factors

1. Has the project budget been defined?
2. Is there a master schedule?
3. Does the master schedule include allowance for subcontractor schedules?
4. Does the master schedule include schedules for owner furnished items?
5. Is the master schedule set up to support transition to turnover by systems?
6. Are all tasks and activities accounted for in the master schedule?
7. Has the critical path been identified?
8. Has the near critical path been identified?
9. Has the master schedule been baselined?
10. Are schedule requirements for construction (including total project duration and milestones) well-defined?
11. Are planned activities durations in line with project conditions?
12. Are the labor productivity rates for major items in line with recent experiences?
13. Has a comprehensive Work Breakdown Structure (WBS) been developed?
14. Does the WBS support commissioning and system turnover?
15. Are the requirements of different stakeholders considered in the planning process?
16. Is there a planned resource loading for the project (in terms of buildup, peak, and rundown)?
17. Is the contractor able to support the requirements for the labor resource requirements of the project?
18. Have all the hold points/handoffs been identified?
19. Have all the hold points and handoffs been integrated in the schedule?
20. Have density/congestion factors been incorporated in the schedule?
21. Is there an adequate space available for each worker to minimize stacking of trades?
22. Has the project logistics plan been incorporated in the schedule?
23. Has the project testing plan been incorporated in the schedule?
24. Has the temporary facilities plan been incorporated in the schedule?
25. Is there a plan in place for resource leveling (especially manpower)?
26. Is the craft-supervision ratio identified?
27. Is the s-curve, in terms of cash flow and rate of expenditures defined?

4. Health/Safety/Security/Environment Factors

1. Have safety goals been set?
2. Is there an emergency plan in place?
3. Is there medical support defined for the project?
4. Is there an environmental management plan in place?
5. Is there a site-specific safety plan in place?
6. Is the project team aligned on the site-specific safety plan?
7. Have site hazard identification (walkthroughs) been completed?
8. Are the site security control procedures in place?
9. Are the pre-employment checks on workers adequate (i.e., drug testing, background checks)?
10. Is there an integrated HSSE plan in place for simultaneous operations?
11. Is there a defined process for communicating changes to the safety plan?
12. Have all the environmental permits that are necessary for starting construction been obtained?

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13. Is on-site safety communication (safety signage/safety board locations) in place?
14. Are there comprehensive blinding, clearing, lockout-tagout, and unit entry plans in place?
15. Are all special safety-related training requirements included in the plan?
16. Is there a safety induction/orientation plan in place?
17. Do the subcontractor's safety plans meet the required standards?
18. Are there planned safety toolbox meetings?
19. Is there a defined work permit process in place?
20. Is there a defined safety supervision plan in place?
5. Execution Factors
1. Are the relevant contracts signed to support construction schedule?
2. Is there a defined process for approving subcontractors and vendors?
3. Is the construction execution plan in place?
4. Is the construction execution plan aligned with the project execution plan?
5. Has the construction execution plan been communicated to the project team?
6. Are there summaries for the contractors' obligations?
7. Have the summaries of contractors' obligations been communicated to the project team?
8. Is there a mobilization plan in place?
9. Are there adequate communication tools in place (including tablets, Wi-Fi, radios, phones, etc.)?
10. Is there a plan in place to ensure coordination among owner, contractors, subcontractors, and vendors?
11. Is there adequate vertical transportation (e.g., cranes, elevators)?
12. Is there a plan for people movement to and from the site?
13. Is there a plan for materials movement to and from the site?
14. Is there a plan for large equipment movement to and from the site?
15. Are all necessary utilities available on site (including electricity, water, drainage, etc.)?
16. Is there a plan in place to minimize out-of-sequence work?
17. Is the project compliant with all applicable permitting requirements and local regulations?
18. Is there an adequate geotechnical investigation of the project site?
19. Is there a plan for people movement within the site?
20. Is there a plan for materials movement within the site?
21. Is there a plan for large equipment movement within the site?
6. Tools and Equipment Factors
1. Have necessary specialty tools/equipment been identified and secured?
2. Is there a contingency plan (e.g., backup, maintenance) in place for critical tools and equipment?
3. Is there a tool and equipment management plan in place for acquisition?
4. Are all pieces of equipment inspected and certified?
5. Are all equipment operators certified?
6. Are special equipment roads, access, assembly areas, and foundations addressed for start of construction?
7. Are all special project tools and consumables identified and secured?
8. Is there a tool and equipment management plan in place for mobilization?
9. Is there a tool and equipment management plan in place for placement?
10. Is there a tool and equipment management plan in place for storage?
11. Is there a tool and equipment management plan in place for movement?
12. Is there a tool and equipment management plan in place for control?
13. Is there a tool and equipment management plan in place for maintenance?

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7. Quality Management Factors
1. Is there a quality assurance plan in place?
2. Have quality assurance practices been defined and communicated?
3. Is there a quality control plan in place for procured items, fabrication and construction?
4. Are there well-defined acceptance criteria for major items?
5. Is the quality control plan communicated among the project team?
6. Are resources (people, tools, systems) in place to perform the quality control plan?
7. Is there a clear definition of process for quality inspection?
8. Are roles and responsibilities defined for quality inspection?
9. Is there an inspection and testing plan in place?
10. Is there a defined process for third-party inspection, including auditing?
11. Is there a defined process for third party vendor or tech support?
12. Is there a clear protocol for cases of non-compliance or corrective action?
8. Change Management Factors
1. Is there a change management process in place?
2. Are the components of the change management process in place sufficient to start construction?
3. Is there a defined change identification process?
4. Is there a defined process for the evaluation and quantification of changes?
5. Is there an entity authorized to issue change orders?
6. Is there a procedure for the implementation of field change orders?
7. Is there a procedure for the update of all documents affected by changes?
8. Is there a system in place for change order tracking?
9. Are there identified payment parameters for changes?
10. Is there a defined process to reconcile change orders to scope?
11. Is there a defined chain of communication of change orders to stakeholders?
12. Are the change management roles and responsibilities clearly defined (included in the RACI matrix)?
13. Is there a shared understanding of the change management process among the project team?
14. Are there procedures in place for turnover of key personnel related to change management?
15. Is there a process for documenting rework activities?
9. Contract Management Factors
1. Has the project team reviewed all the terms and conditions of the contracts to ensure common understanding?
2. Have the notification requirements been communicated among the project team?
3. Is the invoice submittal process clearly communicated and understood by the project team?
4. Have the procedures that should be followed in case of changes been communicated among the project team?
5. Are the implemented contractual incentives and liquidated damages clear?
6. Is the contractual flow between tiers (flow-down clauses) consistent?
7. Are the project completeness criteria well-defined?
8. Is the scope in the prime contract well-defined?
9. Are the legal/contracts team and other technical teams coordinating to draft subcontracts?
10. Is there an established process for claims management?
11. Is there an established system for dispute resolution?
12. Is the contract clear with the warranty period and the processing of interim payments?
13. Has information about the defined delegation/signing authority been communicated among the project team?
14. Are force majeure (excusable non-compensable) clauses communicated among the project team?
15. Is there a system in place to ensure that proof of insurance is provided?

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10. Human Resource Management Factors
1. Has the project team completed a review and analysis of the labor market, including competing projects in the area?
2. Is there plan in place for securing and retaining skilled labor?
3. Is there a plan in place to minimize craft absenteeism?
4. Are craft labor agreement requirements (including restrictive practices) understood by the project team?
5. Have billable labor rates been established?
6. Is there a craft evaluation/qualification program in place?
7. Is there a project-specific-training program in place?
8. Is there a plan in place for securing and retaining the required project staff?
9. Are the procedures for owner approval of hiring and rotating key personnel agreed upon by the project team?
10. Are there on-boarding procedures in place to on-board new hires?
11. Are there procedures in place for the demobilization of workers?
12. Is there an established system to record the attendance of employees to the site?
13. Is there a program in place for Short Service Employees (SSE)?
14. Are there expectations for active employees in place to on-board new hires?
15. Are there progressive discipline procedures in place to on-board new hires?
16. Are there termination procedures in place to on-board new hires?
17. Are there promotion procedures in place to on-board new hires?
11. Stakeholder Management Factors
1. Are stakeholders clearly defined?
2. Is there a plan in place to involve stakeholders?
3. Is the plan for communication with stakeholders (frequency, content, etc.) defined?
4. Is there a public relations and outreach program in place?
5. Is there a specified spokesperson for the project?
12. Risk Assessment and Management Factors
1. Has the project team assessed the risks impacting the construction phase of the project?
2. Is there a clear risk identification and evaluation process?
3. Is there a defined risk analysis and investigation process?
4. Is there a defined risk monitoring and response (including mitigation, avoidance, etc.) framework for: cost?
5. Is there a defined risk monitoring and response (including mitigation, avoidance, etc.) framework for: schedule?
13. Procurement and Material Management Factors
1. Is there a plan in place for managing vendor documents required for construction, commissioning, and startup?
2. Is there a defined plan for storage, staging, and preservation?
3. Is there clear procurement process and supporting systems in place for ordering?
4. Is there a material control system (in terms of security and tracking) in place?
5. Are all bulks (e.g., pipe, valves, cable, and hardware) needed for start of construction purchased and on site?
6. Is there a system in place to pre-package material according to individual work packages?
7. Is there a procedure in place to report over, short, and damaged (O, S, and D) incidents?
8. Is there a field procurement capability on site?
9. Is there clear procurement process and supporting systems in place for tracking?
10. Is there clear procurement process and supporting systems in place for delivery?
11. Are clear procurement process and supporting systems in place for storage?
12. Is there clear procurement process and supporting systems in place for transportation?

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13. Is there clear procurement process and supporting systems in place for installation?
14. Is there clear procurement process and supporting systems in place for surplus?
14. Commissioning Factors
1. Are procedures for turnover (from construction to commissioning) well-defined?
2. Is there a system in place to align construction with commissioning and operations?
3. Is there a defined system for the transition from area-based to system-based?
4. Is the commissioning and startup plan integrated with the EPC schedule?
5. Is there an engagement timeline of the commissioning group?
6. Has a dedicated commissioning leader been identified and communicated?
7. Is there a defined HSSE transition plan from construction to operations?
8. Is there a comprehensive commissioning manual (including all procedures and preservation requirements)?
9. Are the provisions for QA/QC turnover documentation understood by the project team?
10. Is there a mechanical completion checklist in place?
11. Is there a punchlist process in place?
12. Is the as-built documentation procedure understood by the project team?
13. Is the strategy to manage equipment closure communicated and understood?
14. Are pre-startup safety review requirements communicated and understood?
15. Project Controls Factors
1. Is there a progress tracking plan and systems in place?
2. Are the resources to support project tracking deployed?
3. Is there a process in place for responding to delay?
4. Is there a process in place to collect, compile, and report costs?
5. Is there a process in place to monitor and control productivity?
6. Is there an adequate protocol for updating the schedule?
7. Is there a defined document control system in place?
8. Is there a control budget (at the work package level) in place?
9. Is there a cost contingency management plan in place?

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Appendix B:

Clustered Table of Ranked Readiness Factors

Factors	Weight	Cluster
2.04. Have (issued-for-construction) IFC drawings been issued to the point that supports construction activity?	1.848%	1
3.12. Are the labor productivity rates for major items in line with recent experiences?	1.244%	Cluster 2
2.05. Is the schedule for design deliverables compatible with the sequence of construction?	1.230%	
1.20. Does the project team include representative(s) from the procurement team?	1.174%	
2.16. Is the process for reporting RFIs impacting schedule and cost clear?	1.166%	
3.18. Have all the hold points/handoffs been identified?	1.166%	
3.11. Are planned activities durations in line with project conditions?	1.164%	
15.03. Is there a process in place for responding to delay?	1.164%	
14.02. Is there a system in place to align construction with commissioning and operations?	1.142%	
2.09. Have discipline design interfaces been well coordinated?	1.139%	
13.11. Are clear procurement process and supporting systems in place for storage?	1.126%	
14.01. Are procedures for turnover (from construction to commissioning) well-defined?	1.073%	
8.13. Is there a shared understanding of the change management process among the project team?	1.041%	Cluster 3
5.01. Are the relevant contracts signed to support construction schedule?	1.021%	
8.10. Is there a defined process to reconcile change orders to scope?	0.970%	
3.15. Are the requirements of different stakeholders considered in the planning process?	0.966%	
1.15. Do all project team members have the capacity (e.g., availability, experience) to take on the project?	0.963%	
8.07. Is there a procedure for the update of all documents affected by changes?	0.963%	
1.19. Does the project team include representative(s) from the engineering team?	0.960%	
5.11. Is there adequate vertical transportation (e.g., cranes, elevators)?	0.956%	
8.15. Is there a process for documenting rework activities?	0.946%	
3.19. Have all the hold points and handoffs been integrated in the schedule?	0.933%	
1.21. Does the project team include representative(s) from the fabrication team?	0.902%	

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Factors	Weight	Cluster
2.07. Is there a procedure for the timely implementation of receiving vendor information?	0.890%	Cluster 3
3.23. Has the project testing plan been incorporated in the schedule?	0.878%	
2.02. Have all engineering deliverables in construction packages been defined?	0.875%	
15.05. Is there a process in place to monitor and control productivity?	0.875%	
2.03. Are standards and specifications needed to support construction clearly published?	0.827%	Cluster 4
12.02. Is there a clear risk identification and evaluation process?	0.827%	
1.02. Have the project drivers (cost/schedule) been agreed on by the team?	0.824%	
2.10. Have engineering responsibilities been clearly defined?	0.824%	
14.09. Are the provisions for QA/QC turnover documentation understood by the project team?	0.804%	
14.03. Is there a defined system for the transition from area-based to system-based?	0.799%	
8.12. Are the change management roles and responsibilities clearly defined (included in the RACI matrix)?	0.789%	
14.13. Is the strategy to manage equipment closure communicated and understood?	0.780%	
5.20. Is there a plan for materials movement within the site?	0.777%	
14.08. Is there a comprehensive commissioning manual (including all procedures and preservation requirements)?	0.774%	
8.02. Are the components of the change management process in place sufficient to start construction?	0.759%	
11.02. Is there a plan in place to involve stakeholders?	0.759%	
14.04. Is the commissioning and startup plan integrated with the EPC schedule?	0.757%	
8.03. Is there a defined change identification process?	0.756%	
11.01. Are stakeholders clearly defined?	0.749%	
9.10. Is there an established process for claims management?	0.739%	
5.04. Is the construction execution plan aligned with the project execution plan?	0.734%	
3.06. Are all tasks and activities accounted for in the master schedule?	0.721%	
10.05. Are there progressive discipline procedures in place to on-board new hires?	0.712%	
15.02. Are the resources to support project tracking deployed?	0.694%	Cluster 5
2.08. Have commissioning and startup requirements been incorporated in the design?	0.684%	
7.08. Are roles and responsibilities defined for quality inspection?	0.684%	
2.14. Is the process for approval of shop drawings clear?	0.681%	
2.15. Is the process for updating drawings defined?	0.681%	

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Factors	Weight	Cluster
9.01. Has the project team reviewed all the terms and conditions of the contracts to ensure common understanding?	0.673%	Cluster 5
2.17. Is there a defined system of engineering support (including planned on-site availability)?	0.671%	
15.09. Is there a cost contingency management plan in place?	0.671%	
9.08. Is the scope in the prime contract well-defined?	0.668%	
2.01. Have all engineering milestones been developed?	0.651%	
6.13. Is there a tool and equipment management plan in place for maintenance?	0.651%	
3.17. Is the contractor able to support the requirements for the labor resource requirements of the project?	0.633%	
11.03. Is the plan for communication with stakeholders (frequency, content, etc.) defined?	0.626%	
9.04. Have the procedures that should be followed in case of changes been communicated among the project team?	0.623%	
3.10. Are schedule requirements for construction (including total project duration and milestones) well-defined?	0.619%	
9.13. Has information about the defined delegation/signing authority been communicated among the project team?	0.619%	
1.24. Does the project team include representative(s) from the owner team?	0.616%	
1.11. Is the frequency of project team meetings (e.g., daily, weekly, or monthly) defined?	0.608%	
5.05. Has the construction execution plan been communicated to the project team?	0.608%	
7.11. Is there a defined process for third party vendor or tech support?	0.604%	
5.03. Is the construction execution plan in place?	0.599%	
1.23. Does the project team include representative(s) from the sub-contractor team?	0.585%	
2.06. Have clash and interference checks been completed?	0.578%	
10.14. Are there expectations for active employees in place to on-board new hires?	0.565%	Cluster 6
5.10. Is there a plan in place to ensure coordination among owner, contractors, subcontractors, and vendors?	0.561%	
8.04. Is there a defined process for the evaluation and quantification of changes?	0.558%	
5.19. Is there a plan for people movement within the site?	0.555%	
1.14. Do the project team members have all required skills?	0.551%	
13.01. Is there a plan in place for managing vendor documents required for construction, commissioning, and startup?	0.551%	
9.02. Have the notification requirements been communicated among the project team?	0.548%	
14.11. Is there a punchlist process in place?	0.533%	

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Factors	Weight	Cluster
3.21. Is there an adequate space available for each worker to minimize stacking of trades?	0.528%	Cluster 6
14.05. Is there an engagement timeline of the commissioning group?	0.528%	
8.14. Are there procedures in place for turnover of key personnel related to change management?	0.508%	
3.20. Have density/congestion factors been incorporated in the schedule?	0.505%	
14.06. Has a dedicated commissioning leader been identified and communicated?	0.505%	
12.03. Is there a defined risk analysis and investigation process?	0.503%	
5.07. Have the summaries of contractors' obligations been communicated to the project team?	0.498%	
3.05. Is the master schedule set up to support transition to turnover by systems?	0.496%	
1.16. Have the project team members received training regarding project-specific procedures?	0.493%	
1.03. Have the goals and objectives been documented?	0.490%	
12.05. Is there a defined risk monitoring and response (including mitigation, avoidance, etc.) framework for: schedule?	0.490%	
9.07. Are the project completeness criteria well-defined?	0.483%	
14.12. Is the as-built documentation procedure understood by the project team?	0.483%	
1.04. Has the team communicated project goals among themselves?	0.480%	
7.02. Have quality assurance practices been defined and communicated?	0.480%	
7.09. Is there an inspection and testing plan in place?	0.480%	
9.11. Is there an established system for dispute resolution?	0.480%	
12.01. Has the project team assessed the risks impacting the construction phase of the project?	0.480%	
1.22. Does the project team include representative(s) from the construction team?	0.472%	
7.04. Are there well-defined acceptance criteria for major items?	0.470%	
1.09. Have proven leaders been assigned to the project?	0.458%	Cluster 7
10.06. Is there a craft evaluation/qualification program in place?	0.453%	
3.08. Has the near critical path been identified?	0.428%	
5.14. Is there a plan for large equipment movement to and from the site?	0.428%	
4.11. Is there a defined process for communicating changes to the safety plan?	0.425%	
9.06. Is the contractual flow between tiers (flow-down clauses) consistent?	0.425%	
12.04. Is there a defined risk monitoring and response (including mitigation, avoidance, etc.) framework for: cost?	0.425%	

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Factors	Weight	Cluster
7.06. Are resources (people, tools, systems) in place to perform the quality control plan?	0.422%	Cluster 7
9.05. Are the implemented contractual incentives and liquidated damages clear?	0.420%	
7.07. Is there a clear definition of process for quality inspection?	0.418%	
8.06. Is there a procedure for the implementation of field change orders?	0.418%	
6.10. Is there a tool and equipment management plan in place for storage?	0.412%	
14.14. Are pre-startup safety review requirements communicated and understood?	0.412%	
8.08. Is there a system in place for change order tracking?	0.408%	
15.04. Is there a process in place to collect, compile, and report costs?	0.408%	
3.09. Has the master schedule been baselined?	0.405%	
2.13. Is the submittal process defined?	0.400%	
3.26. Is the craft-supervision ratio identified?	0.397%	
8.09. Are there identified payment parameters for changes?	0.392%	
3.25. Is there a plan in place for resource leveling (especially manpower)?	0.389%	
9.03. Is the invoice submittal process clearly communicated and understood by the project team?	0.354%	Cluster 8
2.12. Is there a defined process for responding to RFIs in a timely manner?	0.350%	
5.06 Are there summaries for the contractors' obligations?	0.350%	
13.04. Is there a material control system (in terms of security and tracking) in place?	0.350%	
13.06. Is there a system in place to pre-package material according to individual work packages?	0.350%	
15.06. Is there an adequate protocol for updating the schedule?	0.347%	
6.12. Is there a tool and equipment management plan in place for control?	0.342%	
8.11. Is there a defined chain of communication of change orders to stakeholders?	0.342%	
3.01. Has the project budget been defined?	0.340%	
3.07. Has the critical path been identified?	0.340%	
13.05. Are all bulks (e.g., pipe, valves, cable, and hardware) needed for start of construction purchased and on site?	0.340%	
15.07. Is there a defined document control system in place?	0.340%	
10.09. Are the procedures for owner approval of hiring and rotating key personnel agreed upon by the project team?	0.337%	
5.16. Is there a plan in place to minimize out-of-sequence work?	0.335%	
5.08. Is there a mobilization plan in place?	0.334%	

Factors	Weight	Cluster
13.02. Is there a defined plan for storage, staging, and preservation?	0.334%	Cluster 8
9.12. Is the contract clear with the warranty period and the processing of interim payments?	0.332%	
10.08. Is there a plan in place for securing and retaining the required project staff?	0.324%	
10.02. Is there plan in place for securing and retaining skilled labor?	0.322%	
6.06. Are special equipment roads, access, assembly areas, and foundations addressed for start of construction?	0.315%	
3.04. Does the master schedule include schedules for owner furnished items?	0.312%	
13.12. Is there clear procurement process and supporting systems in place for transportation?	0.309%	
9.09. Are the legal/contracts team and other technical teams coordinating to draft subcontracts?	0.299%	
4.14. Are there comprehensive blinding, clearing, lockout-tagout, and unit entry plans in place?	0.292%	
1.18. Has a system of oversight and governance been established for the project?	0.282%	
15.01. Is there a progress tracking plan and systems in place?	0.282%	
2.11. Has operability been incorporated in design?	0.279%	
15.08. Is there a control budget (at the work package level) in place?	0.277%	
7.12. Is there a clear protocol for cases of non-compliance or corrective action?	0.276%	
10.11. Are there procedures in place for the demobilization of workers?	0.276%	
3.22. Has the project logistics plan been incorporated in the schedule?	0.274%	
3.02. Is there a master schedule?	0.272%	
7.10. Is there a defined process for third-party inspection, including auditing?	0.271%	
14.10. Is there a mechanical completion checklist in place?	0.271%	
3.24. Has the temporary facilities plan been incorporated in the schedule?	0.252%	Cluster 9
4.12. Have all the environmental permits that are necessary for starting construction been obtained?	0.246%	
10.12. Is there an established system to record the attendance of employees to the site?	0.239%	
1.07. Has the organizational chart been distributed and communicated to all pertinent parties?	0.226%	
7.05. Is the quality control plan communicated among the project team?	0.221%	
1.13. Has the project team been formed in a timely manner?	0.218%	
13.07. Is there a procedure in place to report over, short, and damaged (O, S, and D) incidents?	0.218%	

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Factors	Weight	Cluster
6.07. Are all special project tools and consumables identified and secured?	0.214%	Cluster 9
8.01. Is there a change management process in place?	0.214%	
13.13. Is there clear procurement process and supporting systems in place for installation?	0.214%	
3.27. Is the s-curve, in terms of cash flow and rate of expenditures defined?	0.213%	
6.05. Are all equipment operators certified?	0.211%	
7.03. Is there a quality control plan in place for procured items, fabrication and construction?	0.211%	
13.09. Is there clear procurement process and supporting systems in place for tracking?	0.211%	
14.07. Is there a defined HSSE transition plan from construction to operations?	0.209%	
4.06. Is the project team aligned on the site-specific safety plan?	0.208%	
7.01. Is there a quality assurance plan in place?	0.208%	
6.01. Have necessary specialty tools/equipment been identified and secured?	0.206%	
5.02. Is there a defined process for approving subcontractors and vendors?	0.204%	
6.09. Is there a tool and equipment management plan in place for placement?	0.204%	
6.11. Is there a tool and equipment management plan in place for movement?	0.204%	
9.15. Is there a system in place to ensure that proof of insurance is provided?	0.204%	
4.13. Is on-site safety communication (safety signage/safety board locations) in place?	0.203%	
5.12. Is there a plan for people movement to and from the site?	0.199%	
4.10. Is there an integrated HSSE plan in place for simultaneous operations?	0.193%	
6.08. Is there a tool and equipment management plan in place for mobilization?	0.189%	
9.14. Are force majeure (excusable non-compensable) clauses communicated among the project team?	0.169%	
3.03. Does the master schedule include allowance for subcontractor schedules?	0.163%	
6.02. Is there a contingency plan (e.g., backup, maintenance) in place for critical tools and equipment?	0.156%	
3.13. Has a comprehensive Work Breakdown Structure (WBS) been developed?	0.144%	
1.17. . Is there a system for managing cultural diversity (no social/ political impediments among team members)?	0.139%	

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Factors	Weight	Cluster
8.05. Is there an entity authorized to issue change orders?	0.139%	Cluster 9
13.03. Is there clear procurement process and supporting systems in place for ordering?	0.139%	
4.07. Have site hazard identification (walkthroughs) been completed?	0.135%	
4.19. Is there a defined work permit process in place?	0.135%	
5.21. Is there a plan for large equipment movement within the site?	0.133%	
10.04. Are craft labor agreement requirements (including restrictive practices) understood by the project team?	0.131%	
5.17. Is the project compliant with all applicable permitting requirements and local regulations?	0.130%	
3.14. Does the WBS support commissioning and system turnover?	0.120%	Cluster 10
5.13. Is there a plan for materials movement to and from the site?	0.098%	
3.16. Is there a planned resource loading for the project (in terms of buildup, peak, and rundown)?	0.095%	
6.03. Is there a tool and equipment management plan in place for acquisition?	0.080%	
5.15. Are all necessary utilities available on site (including electricity, water, drainage, etc.)?	0.078%	
1.01. Have the project goals been defined?	0.075%	
1.06. Has an organizational chart been developed to assign roles and functions?	0.075%	
13.14. Is there clear procurement process and supporting systems in place for surplus?	0.075%	
4.18. Are there planned safety toolbox meetings?	0.073%	
13.08. Is there a field procurement capability on site?	0.071%	
4.15. Are all special safety-related training requirements included in the plan?	0.070%	
1.08. Are all key project team leadership positions filled?	0.068%	
4.20. Is there a defined safety supervision plan in place?	0.068%	
11.05. Is there a specified spokesperson for the project?	0.037%	
4.09. Are the pre-employment checks on workers adequate (i.e., drug testing, background checks)?	0.025%	
6.04. Are all pieces of equipment inspected and certified?	0.013%	
10.13. Is there a program in place for Short Service Employees (SSE)?	0.012%	
1.05. Has the (Responsible, Accountable, Consulted and Informed) RACI matrix been developed for the project?	0.010%	
1.12. Are the required intervals of reports of the project team (e.g., daily, weekly, or monthly) defined?	0.010%	
4.17. Do the subcontractor's safety plans meet the required standards?	0.010%	
4.02. Is there an emergency plan in place?	0.003%	

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Factors	Cluster
1.10. Is a support system in place to allocate resources?	Fundamental
4.01. Have safety goals been set?	
4.03. Is there medical support defined for the project?	
4.04. Is there an environmental management plan in place?	
4.05. Is there a site-specific safety plan in place?	
4.08. Are the site security control procedures in place?	
4.16. Is there a safety induction/orientation plan in place?	
5.09. Are there adequate communication tools in place (including tablets, Wi-Fi, radios, phones, etc.)?	
5.18. Is there an adequate geotechnical investigation of the project site?	
10.01. Has the project team completed a review and analysis of the labor market, including competing projects in the area?	
10.03. Is there a plan in place to minimize craft absenteeism?	
10.05. Have billable labor rates been established?	
10.07. Is there a project-specific-training program in place?	
10.10. Are there on-boarding procedures in place to on-board new hires?	
10.16. Are there termination procedures in place to on-board new hires?	
10.17. Are there promotion procedures in place to on-board new hires?	
11.04. Is there a public relations and outreach program in place?	
13.10. Is there clear procurement process and supporting systems in place for delivery?	

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Appendix C:

Readiness Factors Ranked within Category

Factor Code	Factors	Cluster
Category 1: Project Team		
1.20	**Does the project team include representative(s) from the procurement team?**	**Cluster 2**
1.15	Do all project team members have the capacity (e.g., availability, experience) to take on the project?	Cluster 3
1.19	Does the project team include representative(s) from the engineering team?	Cluster 3
1.21	Does the project team include representative(s) from the fabrication team?	Cluster 3
1.02	Have the project drivers (cost/schedule) been agreed on by the team?	Cluster 4
1.24	Does the project team include representative(s) from the owner team?	Cluster 5
1.11	Is the frequency of project team meetings (e.g., daily, weekly, or monthly) defined?	Cluster 5
1.23	Does the project team include representative(s) from the sub-contractor team?	Cluster 5
1.14	Do the project team members have all required skills?	Cluster 6
1.16	Have the project team members received training regarding project-specific procedures?	Cluster 6
1.03	Have the goals and objectives been documented?	Cluster 6
1.04	Has the team communicated project goals among themselves?	Cluster 6
1.22	Does the project team include representative(s) from the construction team?	Cluster 6
1.09	Have proven leaders been assigned to the project?	Cluster 7
1.18	Has a system of oversight and governance been established for the project?	Cluster 8
1.07	Has the organizational chart been distributed and communicated to all pertinent parties?	Cluster 9
1.13	Has the project team been formed in a timely manner?	Cluster 9
1.17	Is there a system for managing cultural diversity (no social/ political impediments among team members)?	Cluster 9
1.01	Have the project goals been defined?	Cluster 10
1.06	Has an organizational chart been developed to assign roles and functions?	Cluster 10
1.08	Are all key project team leadership positions filled?	Cluster 10
1.05	Has the (Responsible, Accountable, Consulted and Informed) RACI matrix been developed for the project?	Cluster 10
1.12	Are the required intervals of reports of the project team (e.g., daily, weekly, or monthly) defined?	Cluster 10
1.10	Is a support system in place to allocate resources?	Fundamental

CII Pre-Project Planning Reference 2018 Edition

Factor Code	Factors	Cluster
Category 2: Engineering		
2.04	**Have (issued-for-construction) IFC drawings been issued to the point that supports construction activity?**	**Cluster 1**
02.05	Is the schedule for design deliverables compatible with the sequence of construction?	Cluster 2
02.16	Is the process for reporting RFIs impacting schedule and cost clear?	Cluster 2
02.09	Have discipline design interfaces been well coordinated?	Cluster 2
02.07	Is there a procedure for the timely implementation of receiving vendor information?	Cluster 3
02.02	Have all engineering deliverables in construction packages been defined?	Cluster 3
02.03	Are standards and specifications needed to support construction clearly published?	Cluster 4
02.10	Have engineering responsibilities been clearly defined?	Cluster 4
02.08	Have commissioning and startup requirements been incorporated in the design?	Cluster 5
02.14	Is the process for approval of shop drawings clear?	Cluster 5
02.15	Is the process for updating drawings defined?	Cluster 5
02.17	Is there a defined system of engineering support (including planned on-site availability)?	Cluster 5
02.01	Have all engineering milestones been developed?	Cluster 5
02.06	Have clash and interference checks been completed?	Cluster 5
02.13	Is the submittal process defined?	Cluster 7
02.12	Is there a defined process for responding to RFIs in a timely manner?	Cluster 8
02.11	Has operability been incorporated in design?	Cluster 8
Category 3: Planning		
3.12	**Are the labor productivity rates for major items in line with recent experiences?**	**Cluster 2**
03.18	Have all the hold points/handoffs been identified?	Cluster 2
03.11	Are planned activities durations in line with project conditions?	Cluster 2
03.15	Are the requirements of different stakeholders considered in the planning process?	Cluster 3
03.19	Have all the hold points/handoffs been integrated in the schedule?	Cluster 3
03.23	Has the project testing plan been incorporated in the schedule?	Cluster 3
03.06	Are all tasks and activities accounted for in the master schedule?	Cluster 4
03.17	Is the contractor able to support the requirements for the labor resource requirements of the project?	Cluster 5
03.10	Are schedule requirements for construction (including total project duration and milestones) well-defined?	Cluster 5

CII Construction Quality 2016 Edition

Factor Code	Factors	Cluster
03.21	Is there an adequate space available for each worker to minimize stacking of trades?	Cluster 6
03.20	Have density/congestion factors been incorporated in the schedule?	Cluster 6
03.05	Is the master schedule set up to support transition to turnover by systems?	Cluster 6
03.08	Has the near critical path been identified?	Cluster 7
03.09	Has the master schedule been baselined?	Cluster 7
03.26	Is the craft-supervision ratio identified?	Cluster 7
03.25	Is there a plan in place for resource leveling (especially manpower)?	Cluster 7
03.01	Has the project budget been defined?	Cluster 8
03.07	Has the critical path been identified?	Cluster 8
03.04	Does the master schedule include schedules for owner furnished items?	Cluster 8
03.22	Has the project logistics plan been incorporated in the schedule?	Cluster 8
03.02	Is there a master schedule?	Cluster 8
03.24	Has the temporary facilities plan been incorporated in the schedule?	Cluster 9
03.27	Is the s-curve, in terms of cash flow and rate of expenditures defined?	Cluster 9
03.03	Does the master schedule include allowance for subcontractor schedules?	Cluster 9
03.13	Has a comprehensive Work Breakdown Structure (WBS) been developed?	Cluster 9
03.14	Does the WBS support commissioning and system turnover?	Cluster 10
03.16	Is there a planned resource loading for the project (in terms of buildup, peak, and rundown)?	Cluster 10
Category 4: Health/Safety/Security/Environment (HSSE)		
04.11	**Is there a defined process for communicating changes to the safety plan?**	**Cluster 7**
04.14	Are there comprehensive blinding, clearing, lockout-tagout, and unit entry plans in place?	Cluster 8
04.12	Have all the environmental permits that are necessary for starting construction been obtained?	Cluster 9
04.06	Is the project team aligned on the site-specific safety plan?	Cluster 9
04.13	Is on-site safety communication (safety signage/safety board locations) in place?	Cluster 9
04.10	Is there an integrated HSSE plan in place for simultaneous operations?	Cluster 9
04.07	Have site hazard identification (walkthroughs) been completed?	Cluster 9
04.19	Is there a defined work permit process in place?	Cluster 9

Construction Conference 2018 Edition

Factor Code	Factors	Cluster
04.18	Are there planned safety toolbox meetings?	Cluster 10
04.15	Are all special safety-related training requirements included in the plan?	Cluster 10
04.20	Is there a defined safety supervision plan in place?	Cluster 10
04.09	Are the pre-employment checks on workers adequate (i.e., drug testing, background checks)?	Cluster 10
04.17	Do the subcontractor's safety plans meet the required standards?	Cluster 10
04.02	Is there an emergency plan in place?	Cluster 10
04.01	Have safety goals been set?	Fundamental
04.03	Is there medical support defined for the project?	Fundamental
04.04	Is there an environmental management plan in place?	Fundamental
04.05	Is there a site-specific safety plan in place?	Fundamental
04.08	Are the site security control procedures in place?	Fundamental
04.16	Is there a safety induction/orientation plan in place?	Fundamental
Category 5: Execution		
05.01	**Are the relevant contracts signed to support construction schedule?**	**Cluster 3**
05.11	Is there adequate vertical transportation (e.g., cranes, elevators)?	Cluster 3
05.20	Is there a plan for materials movement within the site?	Cluster 4
05.04	Is the construction execution plan aligned with the project execution plan?	Cluster 4
05.05	Has the construction execution plan been communicated to the project team?	Cluster 5
05.03	Is the construction execution plan in place?	Cluster 5
05.10	Is there a plan in place to ensure coordination among owner, contractors, subcontractors, and vendors?	Cluster 6
05.19	Is there a plan for people movement within the site?	Cluster 6
05.07	Have the summaries of contractors' obligations been communicated to the project team?	Cluster 6
05.14	Is there a plan for large equipment movement to and from the site?	Cluster 7
05.06	Are there summaries for the contractors' obligations?	Cluster 8
05.16	Is there a plan in place to minimize out-of-sequence work?	Cluster 8
05.08	Is there a mobilization plan in place?	Cluster 8
05.02	Is there a defined process for approving subcontractors and vendors?	Cluster 9
05.12	Is there a plan for people movement to and from the site?	Cluster 9
05.21	Is there a plan for large equipment movement within the site?	Cluster 9
05.17	Is the project compliant with all applicable permitting requirements and local regulations?	Cluster 9

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Factor Code	Factors	Cluster
05.13	Is there a plan for materials movement to and from the site?	Cluster 10
05.15	Are all necessary utilities available on site (including electricity, water, drainage, etc.)?	Cluster 10
05.09	Are there adequate communication tools in place (including tablets, Wi-Fi, radios, phones, etc.)?	Fundamental
05.18	Is there an adequate geotechnical investigation of the project site?	Fundamental
Category 6: Tools and Equipment		
06.13	**Is there a tool and equipment management plan in place for maintenance?**	**Cluster 5**
06.10	Is there a tool and equipment management plan in place for storage?	Cluster 7
06.12	Is there a tool and equipment management plan in place for control?	Cluster 8
06.06	Are special equipment roads, access, assembly areas, and foundations addressed for start of construction?	Cluster 8
06.07	Are all special project tools and consumables identified and secured?	Cluster 9
06.05	Are all equipment operators certified?	Cluster 9
06.01	Have necessary specialty tools/equipment been identified and secured?	Cluster 9
06.09	Is there a tool and equipment management plan in place for placement?	Cluster 9
06.11	Is there a tool and equipment management plan in place for movement?	Cluster 9
06.08	Is there a tool and equipment management plan in place for mobilization?	Cluster 9
06.02	Is there a contingency plan (e.g., backup, maintenance) in place for critical tools and equipment?	Cluster 9
06.03	Is there a tool and equipment management plan in place for acquisition?	Cluster 10
06.04	Are all pieces of equipment inspected and certified?	Cluster 10
Category 7: Quality Management		
07.08	**Are roles and responsibilities defined for quality inspection?**	**Cluster 5**
07.11	Is there a defined process for third party vendor or tech support?	Cluster 5
07.02	Have quality assurance practices been defined and communicated?	Cluster 6
07.09	Is there an inspection and testing plan in place?	Cluster 6
07.04	Are there well-defined acceptance criteria for major items?	Cluster 6
07.06	Are resources (people, tools, systems) in place to perform the quality control plan?	Cluster 7
07.07	Is there a clear definition of process for quality inspection?	Cluster 7

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Factor Code	Factors	Cluster
07.12	Is there a clear protocol for cases of non-compliance or corrective action?	Cluster 8
07.10	Is there a defined process for third-party inspection, including auditing?	Cluster 8
07.05	Is the quality control plan communicated among the project team?	Cluster 9
07.03	Is there a quality control plan in place for procured items, fabrication and construction?	Cluster 9
07.01	Is there a quality assurance plan in place?	Cluster 9
Category 8: Change Management		
08.13	**Is there a shared understanding of the change management process among the project team?**	**Cluster 3**
08.10	Is there a defined process to reconcile change orders to scope?	Cluster 3
08.07	Is there a procedure for the update of all documents affected by changes?	Cluster 3
08.15	Is there a process for documenting rework activities?	Cluster 3
08.12	Are the change management roles and responsibilities clearly defined (included in the RACI matrix)?	Cluster 4
08.02	Are the components of the change management process in place sufficient to start construction?	Cluster 4
08.03	Is there a defined change identification process?	Cluster 4
08.04	Is there a defined process for the evaluation and quantification of changes?	Cluster 6
08.14	Are there procedures in place for turnover of key personnel related to change management?	Cluster 6
08.06	Is there a procedure for the implementation of field change orders?	Cluster 7
08.08	Is there a system in place for change order tracking?	Cluster 7
08.09	Are there identified payment parameters for changes?	Cluster 7
08.11	Is there a defined chain of communication of change orders to stakeholders?	Cluster 8
08.01	Is there a change management process in place?	Cluster 9
08.05	Is there an entity authorized to issue change orders?	Cluster 9
Category 9: Contract Management		
09.10	**Is there an established process for claims management?**	**Cluster 4**
09.01	Has the project team reviewed all the terms and conditions of the contracts to ensure common understanding?	Cluster 5
09.08	Is the scope in the prime contract well-defined?	Cluster 5
09.04	Have the procedures that should be followed in case of changes been communicated among the project team?	Cluster 5
09.13	Has information about the defined delegation/signing authority been communicated among the project team?	Cluster 5

Factor Code	Factors	Cluster
09.02	Have the notification requirements been communicated among the project team?	Cluster 6
09.07	Are the project completeness criteria well-defined?	Cluster 6
09.11	Is there an established system for dispute resolution?	Cluster 6
09.06	Is the contractual flow between tiers (flow-down clauses) consistent?	Cluster 7
09.05	Are the implemented contractual incentives and liquidated damages clear?	Cluster 7
09.03	Is the invoice submittal process clearly communicated and understood by the project team?	Cluster 8
09.12	Is the contract clear with the warranty period and the processing of interim payments?	Cluster 8
09.09	Are the legal/contracts team and other technical teams coordinating to draft subcontracts?	Cluster 8
09.15	Is there a system in place to ensure that proof of insurance is provided?	Cluster 9
09.14	Are force majeure (excusable non-compensable) clauses communicated among the project team?	Cluster 9
Category 10: Human Resource Management		
10.15	**Are there progressive discipline procedures in place to on-board new hires?**	**Cluster 4**
10.14	Are there expectations for active employees in place to on-board new hires?	Cluster 6
10.06	Is there a craft evaluation/qualification program in place?	Cluster 7
10.09	Are the procedures for owner approval of hiring and rotating key personnel agreed upon by the project team?	Cluster 8
10.08	Is there a plan in place for securing and retaining the required project staff?	Cluster 8
10.02	Is there plan in place for securing and retaining skilled labor?	Cluster 8
10.11	Are there procedures in place for the demobilization of workers?	Cluster 8
10.12	Is there an established system to record the attendance of employees to the site?	Cluster 9
10.04	Are craft labor agreement requirements (including restrictive practices) understood by the project team?	Cluster 9
10.13	Is there a program in place for Short Service Employees (SSE)?	Cluster 10
10.01	Has the project team completed a review and analysis of the labor market, including competing projects in the area?	Fundamental
10.03	Is there a plan in place to minimize craft absenteeism?	Fundamental
10.05	Have billable labor rates been established?	Fundamental
10.07	Is there a project-specific-training program in place?	Fundamental

Factor Code	Factors	Cluster
10.10	Are there on-boarding procedures in place to on-board new hires?	Fundamental
10.16	Are there termination procedures in place to on-board new hires?	Fundamental
10.17	Are there promotion procedures in place to on-board new hires?	Fundamental
Category 11: Stakeholder Management		
11.02	**Is there a plan in place to involve stakeholders?**	**Cluster 4**
11.01	Are stakeholders clearly defined?	Cluster 4
11.03	Is the plan for communication with stakeholders (frequency, content, etc.) defined?	Cluster 5
11.05	Is there a specified spokesperson for the project?	Cluster 10
11.04	Is there a public relations and outreach program in place?	Fundamental
Category 12: Risk Assessment and Management		
12.02	**Is there a clear risk identification and evaluation process?**	**Cluster 4**
12.03	Is there a defined risk analysis and investigation process?	Cluster 6
12.05	Is there a defined risk monitoring and response (including mitigation, avoidance, etc.) framework for: schedule?	Cluster 6
12.01	Has the project team assessed the risks impacting the construction phase of the project?	Cluster 6
12.04	Is there a defined risk monitoring and response (including mitigation, avoidance, etc.) framework for: cost?	Cluster 7
Category 13: Procurement and Material Management		
13.11	**Is there clear procurement process and supporting systems in place for storage?**	**Cluster 2**
13.01	Is there a plan in place for managing vendor documents required for construction, commissioning, and startup?	Cluster 6
13.04	Is there a material control system (in terms of security and tracking) in place?	Cluster 8
13.06	Is there a system in place to pre-package material according to individual work packages?	Cluster 8
13.05	Are all bulks (e.g., pipe, valves, cable, and hardware) needed for start of construction purchased and on site?	Cluster 8
13.02	Is there a defined plan for storage, staging, and preservation?	Cluster 8
13.12	Is there clear procurement process and supporting systems in place for transportation?	Cluster 8
13.07	Is there a procedure in place to report over, short, and damaged (O, S, and D) incidents?	Cluster 9
13.13	Is there clear procurement process and supporting systems in place for installation?	Cluster 9
13.09	Is there clear procurement process and supporting systems in place for tracking?	Cluster 9
13.03	Is there clear procurement process and supporting systems in place for ordering?	Cluster 9

Factor Code	Factors	Cluster
13.14	Is there clear procurement process and supporting systems in place for surplus?	Cluster 10
13.08	Is there a field procurement capability on site?	Cluster 10
13.10	Is there clear procurement process and supporting systems in place for delivery?	Fundamental
Category 14: Commissioning		
14.02	**Is there a system in place to align construction with commissioning and operations?**	**Cluster 2**
14.01	Are procedures for turnover (from construction to commissioning) well-defined?	Cluster 2
14.09	Are the provisions for QA/QC turnover documentation understood by the project team?	Cluster 4
14.03	Is there a defined system for the transition from area-based to system-based?	Cluster 4
14.13	Is the strategy to manage equipment closure communicated and understood?	Cluster 4
14.08	Is there a comprehensive commissioning manual (including all procedures and preservation requirements)?	Cluster 4
14.04	Is the commissioning and startup plan integrated with the EPC schedule?	Cluster 4
14.11	Is there a punchlist process in place?	Cluster 6
14.05	Is there an engagement timeline of the commissioning group?	Cluster 6
14.06	Has a dedicated commissioning leader been identified and communicated?	Cluster 6
14.12	Is the as-built documentation procedure understood by the project team?	Cluster 6
14.14	Are pre-startup safety review requirements communicated and understood?	Cluster 7
14.10	Is there a mechanical completion checklist in place?	Cluster 8
14.07	Is there a defined HSSE transition plan from construction to operations?	Cluster 9
Category 15: Project Controls		
15.03	**Is there a process in place for responding to delay?**	**Cluster 2**
15.05	Is there a process in place to monitor and control productivity?	Cluster 3
15.02	Are the resources to support project tracking deployed?	Cluster 5
15.09	Is there a cost contingency management plan in place?	Cluster 5
15.04	Is there a process in place to collect, compile, and report costs?	Cluster 7
15.06	Is there an adequate protocol for updating the schedule?	Cluster 8
15.07	Is there a defined document control system in place?	Cluster 8
15.01	Is there a progress tracking plan and systems in place?	Cluster 8
15.08	Is there a control budget (at the work package level) in place?	Cluster 8

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Notes

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