ABSTRACT

ODHIAMBO LINDA. Developing a Fit-for-Purpose Handbook for the Upstream, Midstream and Mining. (Under the direction of Dr. Edward Jaselskis and Dr. Alex Albert).

Projects in the Upstream, Midstream and Mining (UMM) sectors have unique complexity criteria. These projects are often require a high in capital investment; they have significant contractual obligations and may be located in remote locations. These are a few of the characteristics that owners, engineering procurement contractors (EPC) firms and vendors need to take into account from the early stages of planning to achieve success. The Construction Industry Institute's (CII) Research Team 398 aimed at developing the criteria that define project complexity in the UMM sector, a matrix that describes the different levels of complexity and assign tools from the CII database that can be used to manage complexity. The eventual goal is to create a fit-for-purpose handbook for the UMM sector. This project is divided into phases; the first phase is to develop a complexity matrix for the UMM sector. The academic team used convenient sampling and conducted interviews with owners and contractors toward this purpose. The methodology also included reviewing literature from research into complexity, the characteristics of the UMM sector and the incorporating the findings of the RT 305 on Measuring Project Complexity and its Impact together with the PTAG complexity matrix to further understand complexity. The PTAG complexity matrix describes complexity attributes relevant to the mining sector. The result was a complexity matrix that includes factors relevant to all the three sectors.

Developing a Fit for Purpose Handbook for the Upstream, Midstream and Mining (UMM Sector) (Phase 1)

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DEDICATION

I would like to dedicate this thesis to my parents Jacob and Wilbroda Odhiambo, my sister, Lorriane Odhiambo and the rest of my family. I appreciate of all the efforts and sacrifices they made throughout my life to put in positions to excel. I received a strict upbringing under the guidance of these individuals who sacrificed money and the luxuries of life to put me through school.

I would also like to dedicate this thesis to God. His Spirit has encouraged me and guided me when I had roadblocks in my thought process and during my lack of motivation. I am forever grateful.

BIOGRAPHY

I was born in Nairobi, Kenya during a time in Kenya's history that was rife with political uncertainty. One of my earlies memories as a child was my mother telling me to speak in a low voice to avoid someone eavesdropping on us because of our political dissent. I remember thinking that I would love to contribute to my nation to make it such that young people would be free to explore thoughts in a developed nation. I purposed to work hard through primary and high school. I graduated from Pangani Girls High School in 2010 as an A student. I qualified to join any program that I wanted to in college but I opted for pursuing a degree in Civil Engineering at the University of Nairobi because of the tangible contributions that civil engineers make to the landscape of a country.

After graduating with honors after five years of school, I got my first job with a consulting firm in Nairobi and later with a contractor in building designs. I noticed that in order to fully benefit my community, I would need to bolster my resume and I decided it would be best to apply to a Master's program in one of the best institutions for civil engineering in the United States. I have been grateful to work as a Graduate Assistant for the Office of Assessment and Accreditation at North Carolina State University. I learned invaluable information on administrative needs of any institution. I am looking forward to gaining more experience that will allow me to one day start my own consulting firm in Kenya.

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I would also like to give special thanks to my sister, Dr. Lorriane Odhiambo. Your prayers and encouragement were a source of great motivation. I would also like to thank all my friends and family for their continued support.

Lastly, I would like to thank God. Thank you for all the years that you have been by my side and spoken to me when I needed it the most. I will trust you with all my life decisions, big and small.

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1. INTRODUCTION

Construction projects have increased in complexity with the advent of new technologies and alternative project delivery methods. Larger projects, typically considered to be relatively more complex than smaller ones, have different risk profiles that need to be considered. As a result, these projects are more prone to schedule delays and larger budgets than smaller projects (Luo, He, Jaselskis, & Xi, 2017; Flyvbjerg, 2014). A study conducted by the Construction Industry Institute (CII) shows that only 5.4% of the 975 construction projects studied met their planned performance objectives in terms of cost and schedule (CII, 2012). To mitigate the effects of project complexities and to address environmental, social, and corporate governance impacts on project front-end planning, strategies are needed to enable project managers to leverage CII-published industry standards-based project execution plans for each project phase to ensure that the project progresses as planned. By making use of such plans, project managers will be able to gain a better understanding of project performance, thereby leading to more favorable project outcomes.

This project aims to initiate the development of a fit-for-purpose handbook that can assist owners and contractors with improving the predictability of project outcomes by establishing a project delivery approach that is specifically tailored for upstream, midstream, and mining (UMM) projects and expand the utilization of CII tools. In this proposed project, we will begin with an already developed project delivery model developed by PTAG, Inc. for mining projects and adapt its components for all three of the UMM sector areas. In addition, we will explore the tools, guidelines, and checklists that are available in the CII's Knowledge Base (CII KB) database and map those that are most applicable based on project complexity and that can be used in the appropriate phase of UMM project delivery.

This report represents a Phase I effort to begin laying the groundwork for a fit-for-purpose handbook by first understanding the unique project challenges within the UMM sector and using this knowledge to make necessary modifications (if any) to the PTAG Project Delivery Model (PDM). This initial phase explores the current complexity and priority criteria used in the PTAG model to help select an appropriate PDM. Additional phases will investigate CII Best Practices that can address different attributes of project complexity and create a project delivery model that can be used by CII organizations with less mature project management organizations. For less mature Project Management Offices (PMOs), we propose to show which tools should be applied to different phases of projects. Our ultimate goal is to develop the fit-for-purpose handbook with a training guide.

1.1 Research Objectives

The CII's RT 398 team aims at developing a fit-for-purpose handbook for the UMM sector. The handbook will be useful for organizations with mature and those with non-mature project management offices. This handbook will detail rules and resources of project delivery in the UMM sector. The first stages of this process addressed in this paper include:

- Reviewing the project complexity criteria developed by PTAG for the mining industry. PTAG is a global project management services company providing its clients advice on management of capital and major project programs. Refer to Appendix A for a description of the PTAG project delivery model.
- Developing a complexity matrix for the UMM sector that is informed by industry experts, to help owners and contractors understand and manage complexity.

1.2 Research Methodology

The primary methods of data collection were interviews and literature reviews. An interview is a qualitative research method that relies on asking questions in order to collect data. This study used semi-structured interviews with open-ended questions (Alsaawi 2014).

The authors reached out to CII member companies in the UMM sector for purposes of this study. Subject matter experts (SMEs) were the target of this study. These SMEs consisted primarily of 12 owners and 3 engineering procurement and contractor (EPC) experts. The experts have accumulated about 300 years' worth of experience in project management in domestic and international projects. The SMEs had varying years of experience in the different sectors; 120 years in Upstream, 70 years in Midstream, 70 years in Mining and about 50 years in other sectors such as nuclear power plant and other energy generation projects. They currently hold a diverse number of roles as high-ranking decision makers from senior project managers, project managers, facilities and construction managers, and even vice presidents on capital projects.

The RT 398 Academic Team used convenience sampling as the main method of data collection. The interviewees are industry members of CII and are part of the RT 398 Research Team. The academic team created separate groups of interviewees with a background in the upstream, midstream and mining. In addition, we distinguished between owner and EPC firms.

The SME groups were asked to identify strengths and weaknesses of their companies' project delivery method and to validate the complexity matrix criteria. They were provided with two weeks to review the survey and send back the completed questionnaires before the online interviews. During the virtual interviews, we reviewed the survey questions and the interviewees were invited to expound on the answers they had written down.

During the verbal interview, the respondents were asked to further examine the appropriateness of each complexity criteria and associated description, offer suggestions for any additional complexity criteria that will need to be added, and offer related descriptions for any newly suggested criteria.

After the different sectors had given their opinion on the appropriateness of the different complexity criteria, the authors used existing literature and CII publications on the UMM sector on complexity factors. We reviewed and updated the complexity matrix based on the input from the group interviews and these resources.

The next step involved bringing all the interviewees together to ask their opinion on the validated matrix. This was a similar to a focus group discussion. Two reminder emails were sent to the interviewees to request their attendance at the virtual meeting. The reminder emails included an attachment of the edited complexity matrix. Interviewees were asked to give their opinion on the complexity factors that had been included and the adjusted descriptors.

The literature review aimed at understanding complexity in the UMM sector. Our research used the complexity matrix developed by PTAG as a basis for developing a fit-for-purpose matrix. We also adopted great information from previous CII publications such as the RT 305 publication on defining, measuring and managing complexity.

The RT 305 publication did research to define project complexity, detail the statistically significant attributes and categories of complexity and develop the Project Complexity Assessment and Management (PCAM) Tool Application to manage complexity. The PCAM tool was developed for all types of construction projects. This research provided a great background in developing the complexity criteria detailed in the matrix in Table 3.1 (Anderson et al. 2016).

2. LITERATURE REVIEW

2.1 Project Complexity

The definition of project complexity varies depending on the sector of the construction industry and the role of the organization. There is a variety of sectors in construction, from general construction, mining, oil and gas sectors. Within these sectors, there are specialized areas such as construction of offshore wells. The role of the organization could be that of an owner, contractor, vendor or stakeholder. The definition of complexity is dependent on the sector, the unique challenges experienced in those sectors and the role of the organization carrying out the project.

Project complexity consists of diverse interconnected parts that can be operationalized in terms of variation and interdependency (Baccarini 1996). He proposed that a project consists of organizational and technical complexity. The organizational complexity comes about from viewing a project as a task that consists of multiple elements. The technical complexity arises in determining how to transform input to output. Kermanshachi et al. in 2016 further improved on this definition by emphasizing the substantial impact on predictability and performance. The degree of interdependency of tasks can affect the performance of the task where different trades need input from each other.

A simplified definition is that it is the property of a project which makes it difficult to grasp, predict and keep under control its activities even when reasonable information about the project system is provided (Vidal et al. 2011). This definition inadvertently distinguishes complexity from unknowns in a project. It implies that relevant information is at hand, however, this information may be provided in a new context, thereby creating complexity in execution.

Complexity of a process can be defined as the measure of the challenging nature of implementing a production work flow in relation to a number of quantifiable objectives such as time or cost (Gidado 1996). This definition was geared to what project managers could do to measure and deal with project complexity. Interviewing project managers and carrying out literature reviews revealed that there were managerial and technological or operative aspects to complexity. The sources of managerial and technological complexity were linked either to innate or extrinsic factors. Innate factors are those that are part of carrying out a specific activity or they arise from the resources and environment of the activity. These include technological advancements and availability of skilled labor. Extrinsic factors come about in combining multiple activities or tasks to produce workflow. This arises due to the nature of dependencies between the activities. Examples include overlapping of activities of different trades, the rigidity of the sequence and the number of repetitive activities.

Project complexity can be divided into two dimensions: structural uncertainty and uncertainty (Williams 1999). In structural uncertainty, there are multiple elements in a project and their interaction creates complexity. At the same time, the general uncertainty in goals and methods adds to the complexity. This uncertainty occurs when the owner cannot or will not define to precision, the scope of the project. Structural uncertainty refers to the presence of multiple trades required to carry out certain activities on a project.

Edmonds described complexity as the property of a model that makes its behavior difficult to formulate. It relates from the difficulty in understanding how a model will work because of the difficulty in fully comprehending how the parts making up the model behave (Edmonds 1999). This definition asserts that it is possible to gain significant details about the parts that make up the model. In this way, complexity diverges from uncertainty or ignorance.

Research into international megaprojects brought forth other considerations in the definition of complexity. Megaprojects are unique in that they also involve cultural and social complexities in addition to task complexity. These three aspects led them to describe overall project complexity as the degree of manifoldness, interrelatedness and consequential impact of a decision field (Brockmann and Girmscheid 2007). Task complexity is intensity of activities within a prescribed space and time. Social complexity refers to the number and diversity of actors whereas cultural complexity refers to the cultural diversity. These are aspects that are common in international projects and need to be managed in an adept manner.

CII's RT 305 investigated articles on project complexity and came up with another definition. They defined complexity as the degree of interrelatedness between project attributes and interfaces, and their consequential impact on predictability and functionality. This is reflective of how the attributes of a project such as scope, stakeholders and schedule interact with other attributes and attributes outside of the project. It is important to note that complexity is not defined in terms of the physical traits of a project such as quantity of materials and facility technology. This allows complexity to be defined across diverse industries.

2.2 Differences between Risk, Uncertainty and Complexity

Uncertainty is the state of lack of clear definition or identification. Its impact could be positive or negative. Whereas, risk is a state of uncertainty where some possible results have an undesired effect or major monetary loss. Risk can be quantified while uncertainty cannot be measured (Kermanshachi et al. 2016). On the other hand, complexity can be a source of risk as well as a source of opportunities. Uncertainty in construction arises from the environment, the design or the tasks involved in creating the design (Gidado 1996). Gidado went further in categorizing uncertainty factors into several divisions. The lack of proper scope definition on activities is a clear source of uncertainty. In addition, the novelty of the inputs and the environment presents another division of uncertainty. The unpredictability of the environment serves to add uncertainty in the means and methods to be employed. For example, in a case where the as-built construction drawings lack sufficient detail on certain elements, those drawings should not be used a trusted source of information. He used these divisions in a model to show how complexity and uncertainty interact (Wood and Ashton 2010).

2.3 Types of Complexity

The types of complexities that are of major concern to a project manager are organizational and technological complexities (Baccarini 1996). A project may be organized in terms vertical and horizontal units. In vertical units, there is a top down managerial consideration for directives. Horizontal units are found in projects where multiple departments have to sign off on certain tasks. This creates organizational complexity in terms of the degree of interaction.

Organizations tend to structure themselves into different departments that are interdependent. Serial interdependence is a form in which one department produces output that forms the input for another department. However, another form of interdependence referred to as reciprocal interdependence is more complex. This is because one department produces output that is the input for another department, whereas the receiving department produces output that is then processed by the initial department (Thompson 1967). Presence of a large number of stakeholders and the lack of defined project roles can be grouped under organizational complexity (Wood and Ashton 2010).

Baccarini went on to discuss the aspect of technological complexity by differentiation and interdependency rather than by difficulty of task performance. Differentiation refers to the assortment of tasks, inputs, outputs or the number of sub-contractors involved in a project.

Interdependency is similar to the types of organizational interdependency. However, this interdependence is between tasks and specialty sub-contractors. Where one specialty is reliant on another to complete an activity before their activity can start. The sheer physical size of a project, number of trades involved and the degree of physically complex roles involved make up technological and operational complexities (Wood and Ashton 2010).

International construction joint ventures are considered complex for many reasons including task, social and cultural complexities (Gerhard and Christian 2008). International projects are a huge undertaking by nature; this task complexity is mitigated by use of smaller departments that undertake specific tasks. The goal is to break down tasks into manageable tasks and having qualified individuals spearhead those groups. Socio-cultural complexities arise from bringing together individuals of varied background and upbringing. One common example is the emphasis on timeliness by different cultures. This kind of complexity is abated as time goes by and the partners in the joint venture are able to establish trust. The capabilities of groups to perform their tasks becomes apparent. This dispenses with the need of budgeting for social controls and in so doing constitutes savings for the organization. This is effectively a win-win situation.

Some authors have used broader categorizations for types of complexities. One example is structural complexity that includes the size of a project, the variety of tasks in fulfilling the project requirements and the degree of interdependence (Geraldi et al. 2011). This interdependence ranges from task to trade dependencies (Baccarini 1996). It also refers to the relationship between stakeholders. On the other hand, the category of dynamics refers to the changes in tasks, project management team, suppliers or even the environmental context. It is used to refer to the changes in scope and the frequency of scope changes. The rate at which a project is to be delivered is a factor in complexity according to some authors (Geraldi et al. 2011). However, pace is measured correctly when it is defined relative to some optimal measure that is unique to the organization. The pace of a project determines the managerial requirements. Fast-paced projects have shorter feedback loops when compared to slow paced projects.

Socio-political complexity is expressed when multiple stakeholders have differing goals. The differing objectives create uncertainty and in some publications, this type of complexity, falls under uncertainty. However, it can also be defined as a lack of commitment from stakeholders or any challenging relationships between internal and external stakeholders (Geraldi et al. 2011). This type of complexity is critical to modern day projects that are watched closely by the public. The scope of stakeholders has expanded to include anyone who has access to public records and is interested in the impact that the project will have. This state of affairs has put projects in the eye of the communities that surround them and in some cases; the media gets involved given the far-reaching effects of social media.

Some authors like Wood and Ashton used literature review on complexity and interviews of industry experts to assess factors of complexity. Their assessment deduced five major groupings to include up to forty-six factors. These factors are not exhaustive, they include; organizational, technological, planning, environmental and uncertainty factors. Some of the factors have been touched upon in preceding paragraphs. However, the environmental aspect refers to projects where the site is in a restricted, public, historic or contaminated environment (Wood and Ashton 2010). There are also legal aspects that are associated with foreign environments.

2.4 Stage Gate Project Delivery

The concept of a stage gate system was been analyzed by notable researchers. These researchers analogized it to process management (Cooper 1990). The process is managed by use of checkpoints or gates to assess the viability of proceeding with the process. In terms of production control, deliverables are identified for each gate. In addition, there are quality gages that the product should clear before moving on to the next stage.

The deliverables and criteria vary from industry to industry and even among companies within the same industry. Each gate is categorized by a set of inputs. The inputs are deliverables that the project team must bring to the gate, without which the process cannot be evaluated. Criteria are used on the deliverable to determine the output at the gate (Cooper 1990). The output is whether to proceed with the process or how to improve the process in the next phases. At the end of every phase, metrics are put in place to assess whether the objectives have been achieved and whether the project is on track within time and budget (Rui et al. 2017).

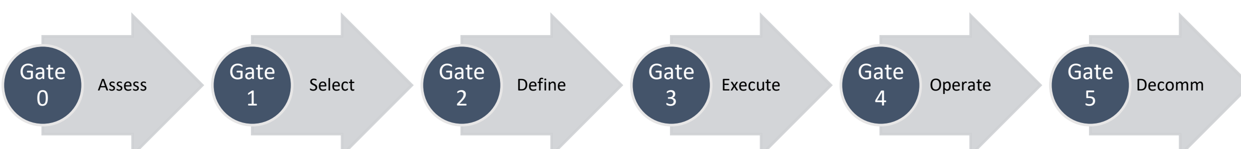

Figure 2.1. Cooper's Stage Gate Project Delivery Process

Mining

Oil and gas mining projects can be found on both onshore and offshore rigs. Given the extensive capital investments in these type of projects, managers make decisions to move from one phase to another at the gates by assessing certain metrics. Cost metrics can be applied at multiple phases. An example of cost growth metric is the ratio of the difference between actual and estimated costs to the original estimated cost (Rui et al. 2017). This is an example of a cost review.

Other metrics include schedule, safety and quantity metrics. Schedule metrics keep track of the time constraint on a project by comparing the ratio of the pipeline installation duration to the pipeline length for midstream or upstream projects. Safety can be assessed using total recordable injury rates (TRIR) or Experience Modifier Rate (EMR). These rates compare the number of injuries reported on a project to standard number of injuries.

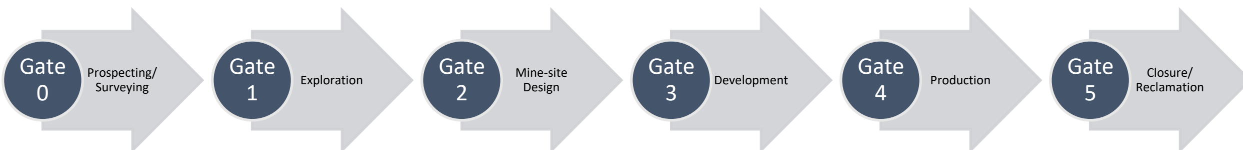

Figure 1.2. Mining Project Delivery Process

Source: Chapter 1 of the Guidebook for Evaluating Mining Projects

Table 2.1. Processes in Stage Gate Delivery

Opportunity stage	**Viability stage**	**Planning stage**	**Execution stage**		**Completion stage**
Planning	Design Engineering	Detail Engineering	Detail Engineering	Cost Engineering	Commissioning
Conceptual	Environmental Review	Environmental and Permitting	Environmental and Permitting	Permit finalization	Start-up
Engineering	Estimating	Cost Engineering	Procurement	Pre-commissioning	Ramp-up
Environmental	Cost Engineering		Construction		Turnover
Review	Prefeasibility Study		Cost Engineering		
Estimating	Feasibility Study		Construction		
Scoping Study			Procurement		

Table extracted from Hickson and Owen's "Project Management for Mining" (Hickson and Owen 2022)

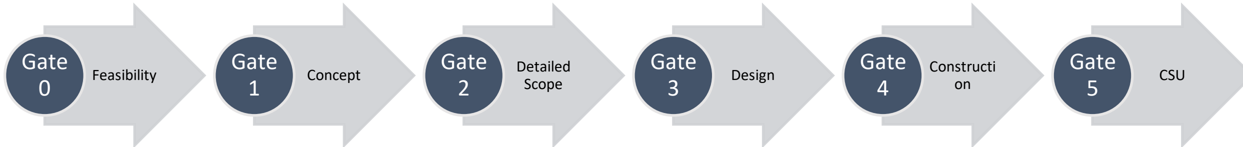

Figure 2.3 CII Phase Gate Delivery Process

Figure 2.3 above illustrates the phases that CII RT 213 deduced as essential to effective project delivery. The circles represent gates that must be addressed before moving on to the next phase.

In order for an organization to assign requirements to a project, the level of complexity is first defined. Project managers develop rigor based on the derived level of complexity. According to Thomas, the level of rigor should begin as early as in the planning phase and should include the Project Management Plan (PMP). This PM plan can be as short as fifty or as long as hundreds of pages depending on the complexity of the project. In his paper, he discussed several activities of the project management process within the nuclear industry that link to the level of rigor. These activities include scope definition, procurement planning, cost estimating and quality management among others. For example, quality management involves developing project specific quality checks and inspections for a highly complex project. However, obtaining certifications may suffice for a low complexity project.

2.5 How to Measure Complexity

Gidado uses von Neuman's mathematical principles to deduce a measure of complexity. One principle is that complexity can be measured if it is related to a things such as the dimension of a state space, the length of a program or the magnitude of a cost in money or time. Another principle is that systems behave in a simple manner below a certain threshold (von Neuman as cited by Gidado 1996)

The tasks can include all elements that should be represented on a Gantt chart; from drafting, procurement, meetings and construction of building elements. Gidado theorized that a component in a task can be a source of complexity due to the resources used or the environment in which the task is carried out. He showed that these components have a linear relationship with time and cost, that is, if the complexity of the component increases, the amount of time required to carry out the task also increased.

According to Gidado, complexity, $C,$ is directly proportional to the duration that a complexity component affects a complex task or role, represented as $t_{i\ conplex}$. Complexity is also inversely proportional to the workflow production time, T_p. If the amount of time spent on work that includes complex elements, the complexity will decrease. He combined these two equations to develop an equation for complexity for serial and overlapping activities.

$$C = \frac{t_{i\ complex}(K-1)}{T_p} \qquad \text{Equation 1.}$$

Where K is the ratio of the total duration of the activity to the duration that a complexity component affects a complex task. K can be determined by using in-house databases and comparing standard task durations to durations where complexity was a factor (Gidado 1996).

He used Equation 1 to further derive the effect on the total workflow production time, it is represented below:

$$T_{total} = T_p + T_p C_o \qquad \text{Equation 2}$$

Where C_o is the complexity coefficient, from this relationship we can deduce that the total production time in a series of tasks is the initial production time in addition to the effect of complexity on production time.

These equations can also be used for multiple serial or overlapping activities that contain complexity.

Project complexity measures are developed from interviews and review of case studies. Wood and Ashton developed a model around five themes; planning and management, organizational, operational and technological, environmental and uncertainty. They used the data to develop a Significance Index (SI). After the user scores a project based on these themes and their factors, the model generates a complexity exposure score. It also highlights areas of great complexity that need improvement (Wood and Ashton 2010). The second stage highlights the areas of complexity and generates questions to better manage complexity. The user is expected to use these questions to gather more information about the project needs and develop deliverables that can manage the complex aspects of the project. This model is uses mathematical calculations in the background and a qualitative approach in the foreground.

The Delphi technique was used to develop complexity factors in the building industry in China (Xia and Chan 2012). The author selected seasoned professionals from diverse sectors. The interviewees were asked to develop at least five factors of complexity in the first round of interviews. The author analyzed the factors and selected the top seven reoccurring factors. In the second round of interviews, the author asked the same group of individuals to rate the factors on a five-point Likert scale. Their responses were used to provide an average score to all the factors. The factors were ranked according to their mean scores. The means scores of the seven factors was used to calculate a weighting factor from the equation below.

$$W_{CMi} = \frac{M_{CMi}}{\sum_{i=1}^{6} M_{CMi}} \quad \text{Equation 3}$$

Where:

W_{CMi} represents the importance weighting of a particular top six complexity criteria

M_{CMi} represents the mean rating of a particular top six complexity criteria

$\sum M_{CMi}$ represents the summation of mean ratings of the top six complexity criteria

This paper suggested that the weighting factor should be used with a complexity rating score for every factor to develop an overall project complexity index (CI). However, the author did not provide a means of establishing a complexity rating score for the six factors of complexity.

Project complexity is measured using the Analytical Hierarchical Process (AHP) technique (Vidal et al. 2011). He began by visualizing a project as a system with goals, an internal structure and activities that evolve over time. The initial assessment derived 70 project complexity factors. He categorized these factors into two types: technological or organizational. The descriptions focused on size, interdependencies, context-dependencies and variety.

To create a user-friendly model, the factors had to be reduced. He did this by carrying out an international Delphi study with experienced professionals from across the world. At the end of the study, the panel settled on 18 factors; 2 technological and 16 organizational factors.

The AHP technique has gained prominence in assessing multi-criteria factors in project management. This was the next step in Vidal et al.'s research.

2.6 Models of Project Complexity

Interdependence of activities in a project have led to the use of project complexity models in an attempt to comprehend complexity. In a workflow, subsequent activities are dependent on the preceding ones. The difficulty in quantifying the effect of the interdependencies has led researchers to rely on experience of the project managers. He described structural complexity, that is, having stable qualities and dynamic complexity that is, having qualities that may change with time. Maylor interviewed project managers to understand and construct their ideas of complexity with regard to management of projects. Successive workshops developed more than a hundred concepts based on five categories, that is, the mission, organization, delivery method, stakeholders and project team (MODeST) (Maylor et al. 2008).

The concepts once framed as questions, steer project managers to think about granular aspects of a project that may or may not influence project complexity. His work showed how structural complexity is assessed together with dynamic complexity. For example, it is important to understand which stakeholders are engaged in a project, that is, structural complexity. It is also important to consider the frequency with which these stakeholders are to be updated and their level of involvement in different phases of the project.

2.7 Project Complexity Models and the PTAG Complexity Model

Complexity models encompass both theoretical requirements and user requirements. In order for a complexity model to be considered effective, it must meet specified theoretical and user requirements (Vidal and Marle 2008). User requirements include validity of the model, the intuitiveness of the model. The model's ability to suppress unnecessary detail; the user should not encounter attributes that do not add to understanding complexity. In addition, the computability of a model refers to the use of weighting factors or values used to calculate the overall complexity from the individual attributes.

<u>Unique features associated with UMM projects</u>

Upstream Projects

This typically refers to projects that construct facilities for production and stabilization of oil and gas (Devold 2006). Feasibility studies determine whether a source is worth exploiting. Exploitation is in the form of on land or off shore drilling. Drilling is followed by operating the wells that bring crude oil and natural gas to the surface (Herkenhoff 2014).

1. Upstream projects are located in remote areas, either in the middle of the ocean or in isolated locations on land. This leads to budgeting for infrastructure to access the site, also, purchase orders and sub-contracts need to be issued early in advance with this in mind (Ruqaishi and Bashir 2015) failure to which, delays during taking off may occur. These delays often result in cost overruns (Jergeas and Ruwanpura 2010).
2. Oil spills may be rare but they have a devastating effect on the capital share of the companies involved in an oil spill. The potential negative publicity and decrease in share prices arising from oil spill events is enough to ensure that the environmental policies in these projects are rigorous. The environmental, health and safety programs are written with great detail depending on the nature of the project.
3. The push toward green economies and the negative consequences associated with disasters such as oil spills are creating higher regulatory demands on upstream projects. In 2012, the United States passed a law that limited the amount of CO2 that coal plants could emit. In Europe, some countries have banned fracking or have put significant limits on its use (Herkenhoff 2014). The regulatory requirements that need to adhered to during a project may negate the benefits of carrying out a project. This has caused some countries to postpone projects while terminating other projects.

The regulations in the upstream sector are governed my numerous bodies as is the case in a many western nations. Globalization is forcing companies to adhere to both national and international regulation agencies. Regulatory bodies in American are numerous and have a wide range of responsibilities. The Bureau of Land Management within the Department of Interior regulates drilling permits/leases within federal or Native American land. It offers the leases at auctions. The US Department of Transportation Pipeline and Hazardous Material Safety

Administration inspects pipelines to ensure they comply with safety regulations. In between there are other agencies and policies set to protect consumer and investor interests, ensure equal access to would be shippers and even require companies to set up facility management plans in case of a breach to the facilities.

The regulations extend to territories not owned by the USA if American companies are operating in those regions. Such regulations are relevant for off shore operations. They serve to standardize the products of the oil and gas industry. Some examples of international organizations include the American Society of Testing and Materials (ASTM) and the International Standards Organizations (ISO).

Midstream Projects

This typically refers to projects that treat, store and distribute gas and petroleum (Herkenhoff 2014).

Mining

1. Exploration includes prospecting, seismic and drilling activities that take place before the development of a field is undertaken (Devold 2006). Some of the unique feature of mining projects are in the initial stages where exploration portfolios are created. Exploration is necessary for companies to determine the presence of ores. The discovery of high grade, easy geologic conditions, or low-cost concentration may encourage a company to mine the ore and the reverse is true (Balci and Kumral 2022). There is a significant amount of coordination in mining projects to ensure that before one mine is depleted, there is another mine ready to move past the exploration phase.
2. Globalization is forcing innovation in the mining industry. There is a push from the World Bank for some industries to employ social risk management strategies. This

recognizes the potential effects that mining processes have on the environment and community and the pre-emptive need to manage the risks (Balci and Kumral 2022).

3. Sovereign states are implementing strategic policies and some of them are focused on the mining sector. The location in which a mining project is located will influence the regulatory environment and hence the policies that will need to be considered during front end loading (Balci and Kumral 2022).
4. Social and environmental factors that influence site selection are important and may take precedence in mining projects. This is because sustainability in mining is a multi-stakeholder issue. The presence of multiple stakeholders creates complexity as the developer and the regulatory bodies have different importance criteria (Dey and Ramcharan 2008)
5. There are increasing technological challenges in the mining sector. These may arise from issues such as depletion of resources that forces companies to setup new mining sites in areas that were previously deemed too dangerous or where the available ore is of a lower quality forcing innovation in the technological resources needed to mine the resource.

3. DISCUSSION OF FINDINGS

3.1 Status of Project Delivery Methods

The interviewees work for companies that have relatively mature standards of operations in all phases of the project life cycles. The interviewees rated their companies with an average score of 3.9 in project delivery. The rating was on a five point rating scale with one denoting "not very effective" and five, "highly effective". This means that they perceive their companies as having effective project delivery methods in place. This still leaves room for improvement.

The survey responses revealed that there is opportunity for improvement in the pre-feasibility phase. There are opportunities to develop consistent key performance indicators (KPIs) within the UMM sector across international boundaries by using economic indicators. This will improve the accuracy of the information that used in making "go/no-go" decision at this stage. Technology experts should be consulted in the pre-feasibility phase to provide reliable accurate insights into design and technological alternatives

Front end planning (FEP) includes the feasibility, concept and detailed scope phases. This phase provide the most opportunity for improvement according to the results. Respondents identified resource allocation as one of the keys to realizing the benefits of FEP phase. Resources include providing financial, personnel and upper management support. Once FEP has dedicated time on the project schedule, the personnel have the opportunity to develop adequate metrics for the stage-gate process.

Firms that engage in large capital expenditure projects have a strong execution strategy. The respondents linked the opportunities for improvement here as tied to the planning phase because the amount of rework and scope changes will depend on the deliverables from the FEP. The use of work packaging and model efforts at a task level will improve the workflow during field construction. In the event where there are scope changes, they should be limited to the initial timeline of the projected execution schedule. However, companies should already have plans on managing changes that may occur during construction. Providing an adequate budget for controls and monitoring during this phase is key to meet client needs. In addition, legal requirements may force owners and EPCs to subcontract work to less experienced subcontractors. For example, foreign contractors are required to have a number of local contractors on the team.

Respondents pointed out the benefit of having stakeholders engage in the planning process. Others opportunities for improvement in this phase are to carry out final project reviews and incorporate assessment results into a database for future projects. That is, there is a need to ensure a continuous loop including the lessons learned from the commissioning of the projects.

3.2 UMM Project Complexity Matrix

Table 3.1 shows the complexity matrix developed from results of the research study.

Table 3.1. RT 398's Project Complexity Matrix

Category	Attribute	Complexity Level		
		Low	Medium	High
Project	**Strategic importance of the project**	Maintenance/Sustainable/ Value Engineering / Quick win / Non-urgent work.	Compliance/Operation Capital Growth type of project required to enable continuous operations.	Strategic, mandatory, or urgent project required for the long term benefit or survival of the company or dictated by
	Size (CAPEX Estimate at Completion (EAC)) (suggested ranges are relative to each organization)	Small (<5% of company capital expenditures over 5 year planning period)	Medium (5-25% of company capital expenditures over 5 year planning period)	Large (>25% of company capital expenditures over 5 year planning period)
	Frequency of delivery	Delivered multiple times per year	Not a frequently repeated project but completed one similar project in the past 5 years	Not performed similar project within past 5 years
	Impact on organization	Can be standalone or has minimal scope, budget, and/or schedule impact on other areas of the organization	Scope, budget, and/or schedule have some impact to other areas of the organization	Scope, budget, and/or schedule have significant impact to other areas of the organization
	Commissioning and Startup (CS	CSU within capacity and capability of the existing Operating organization	CSU within the capability of the Operating organization with minor gaps in capacity or skills	New Operating organization required
Stakeholder Management	**Internal** (e.g., stakeholders within the Owner's organization (e.g., HSE, Operations and Marketing) but outside the project team (PMT and contractors))	Very little interaction or coordination necessary with internal stakeholders	Some interactions or coordination with internal stakeholders to ensure alignment and review plans or incorporate changes (e.g., weekly or monthly). Interface agreements may or	Frequent and formal interface management with internal stakeholders requiring documented interfaces and full time staff dedicated to managing interfaces.
	External (e.g., stakeholders outside the Owner's company and outside the project team which includes the Owner's PMT and those contractors that it supervises). External interfaces include: Host Government, Co-venture partners (if any), NGO's, other projects and their contractors operating in the same area (if not within the same company), Landlord (if applicable), Labor unions, Lenders/Financing, etc.	Very little interaction or coordination with external stakeholders	Some interaction and coordination with external stakeholders	Frequent and formal interface management with external stakeholders
Governance	Level of authorizing approvals and duration of receiving proposals; Level of Control	The project manager has the authority to release most of the work orders and approve the change orders	Some work orders and change orders needs project mangers approval while others require multi-level authorization.	Most work orders and change orders requires multi-level authorization
Fiscal Planning	Funding as it pertains to the amount and ability to execute project without delays (cashflow availability)	Small, Sustainable, annual maintenance project. Funding is included in the corporate's annual maintenance budget.	Multi-year capital project. Full funding is available, but cash will only be released for each phase as planned	Multi-year capital projects with the Project funding tied to the global commodity (oil, gas, precious metals, etc.) prices. Expansion project with partial funding available and the rest is tied to the profits generated by the
Quality	Quality of suppliers, subcontractors, and contractors	Adequate supply of capable suppliers and contractors	Some constraints on capable suppliers and contractors	Significant constraints on capable suppliers and contractors

Table 3.1. (Continued)

Category	Attribute	Complexity Level		
		Low	**Medium**	**High**
Safety and Health	**Construction Safety and Health**	Safety management does not present unusual challenges and work operations are expected to be less dynamic in a largely controlled area. No significant high-energy hazards that require unconventional safety management methods or regulatory requirements	Safety management present some unusual challenges and work operations are expected to be somewhat dynamic and uncontrolled. A relatively low number of high-energy hazards and no unconventional safety management methods or regulatory requirements	Safety management presents unusual challenges as a result of highly dynamic and unique work operations (e.g., work involving operational brownfield facility, multiple contractors with their own safety management efforts, mutiple trades working alongside each other, etc.). Significant high-energy hazards expected (e.g., work involving or alongside heavy equipment, pressurized piping, heights, high voltage powerlines, excavaton or trenching operations, confined spaces, fammable substances, etc.) that will need unconventional safety management
Legal	**Environmental**	Project has minimal environmental impact and requires minimal regulatory interface. Environmental inspections to be only conducted upon project completion	Project has moderate environmental impact and/or regulatory requirements. Frequent (monthly quarterly, etc.) project team interface with environmental regulatory organizations and frequent scheduled environmental inspections are required.	Project is environmental/ regulatory driven, and detailed Environmental Management Planning and permitting are required. Daily project team interface with environmental regulatory organizations and daily environmental inspections are required.
	Security	Project has minimum site security requirement, and can be managed internally with minimum security resources.	Project has moderate security requirements to guard the site and secure delivered equipment and material. Dedicated 24/7 on-site security personnel and surveillance and access system are required.	Project site is located in an area known for thefts and/or site demonstrations are expected. Detailed Site Security Management Plan is required. Dedicated 24/7 on-site security personnel and surveillance and access system are required. Daily project security team interface with local law enforcement authorities and [illegible]
	Permitting as it pertains to the number of permits needed, type of permits and their requirements, ease of obtaining them and their impact on the critical path if the permits are delayed	Normal permit requirements with minimal delay impact to project	Moderate permit issues with controllable delay impact to project	Substantial permit issues which can jeopardize the success of the project
	Contracting requirements (e.g., payment terms, performance guarantees, insurance requirements, and delay damages)	Contractual requirements are standard and well understood by all parties	Moderate number of competing objectives between contractual requirements such as delivery schedules, financial targets and support capabilities	Significant competing objectives between contractual requirements such as delivery schedules, financial targets and support capabilities
Interfaces	**Operational interfaces** (e.g., shut downs and field work during normal facility operations including hot taps, lifting over live equipment, electrical and control system tie-ins, etc.)	No shutdown required and no schedule contraints--work can be performed unhindered	Work can be delivered during planned shutdowns with low risk of impact on the current planned shutdown. Some work can be delivered during planned shutdowns, but it has a high risk of extending the current planned shutdown (doesn't require a dedicated shutdown)	Requires extensive shutdown with active operational interface and complex tie-ins (i.e., the project is not within a planned shutdown)
Execution Target	**Pace of project schedule** with implicatons pertaining to fast tracking Front End Loading and round-the-clock work and shift planning	Normal pace (>10% slower than industry norm/benchmarks)	Moderately accelerated pace (within 10% to 20% of industry norms/benchmarks)	Significant project pace (>20% faster than industry norms/benchmarks)
	Adequacy of project budget with implicatons of possible cost overruns	Quick Win / Annual repeat project. Budget is known to the Project Owner's organization. Detailed/Definitive Estimate with -10% to +15% estimate accuracy and adequate cost control process defined and cost controls tool is properly implemented. The Cost control process is not known	Intermediate/Parametric Estimate with -15% to +25% estimate accuracy. The Cost control process is not known by the project team and/or the cost control tools are not properly implemented	Early/Rough Order of Magnitude Estimate with ±50% estimate accuracy. The Cost control process is not well defined and the cost control tools are not properly implemented

Table 3.1. (Continued)

Category	Attribute	Complexity Level: Low	Complexity Level: Medium	Complexity Level: High
Design and Technology	Scope Definition	Project activities, timelines, deliverables, stakeholders and boundaries are clearly defined and understood by all teams	One or few stakeholders are yet to define project activities and boundaries. Scope is fully defined but some deliverables may be subject to change leading to contingency planning	Multiple stakeholders are yet to finalize the input for the scope by the beginning of the FEP stage
	Technology maturity	Mature technology with previous owner experience	Mature technology within industry, but limited or no experience within Owner's organization. Known technology within industry, but step out from previous size	Emerging or new technology; new to Owner and new to industry
	Design complexity	Little or no design complexity. Project scope is clearly defined and field operations can commence after design is complete. Complexity of design is well understood and team members are well versed. Field operations will commence	Complexity of design is understood by most team members with moderate levels of sophistication. Field operations may need to commence before design is complete or project scope is clearly defined.	Complexity of design is not well understood or is highly sophisticated. Field operations may need to commence before design is complete or project scope is clearly defined.
Location	**Location-based constraints pertaining to remoteness** (e.g., impact on personnel and material logistics, infrastructure availability for local labor or procurement, etc.)	Minimal locational constraints on field operations	Moderate impact of locational factors on field operations.	Significant locational impact (e.g., remote operations with access challenges)
	Seasonality impacts (e.g., normal to extreme weather conditions, normal to constrained delivery windows, etc.)	Minimal seasonal impact	Moderate seasonal impact	Significant seasonal impact
	Number of Locations during the Detailed Engineering/ Design phase of the project	In-house Detailed engineering/Designing	Detailed engineering/Design completed in a few locations	Detailed engineering/Design completed at multiple international locations
Scope Definition	Goal Clarity	Project goals are clear and known to the team. Alignment workshops conducted. The Project goals and priorities are well-defined and understood by the project stakeholders.	Project stakeholders are aligned on most project goals and priorities. 1-2 alignment workshop sessions are still required to get all stakeholders fully aligned and clarify project goals and priorities.	The project stakeholders are not aligned on the project goals and priorities and/or project goals are not clearly communicated. Several alignment workshop sessions are required to clarify the project goals and get the project
Project Resources	Project Management Team (PMT)	PMT is staffed with a part-time effort from one or more Owner's employees.	PMT is staffed using a combination of full-time and part-time Owner's employees. PMT is staffed using a combination of Owner's employees supplemented with contract employees from staffing agencies	The owner's organization is insufficient to staff PMT, even if supplemented with agency personnel. Professional Project Management Contractor required to oversee engineering, construction, or EPC
	Material availability	Materials and alternatives can be sourced easily and quickly	Some of the required materials are relatively difficult to acquire	Materials required on the critical path are in limited supply. The cost of the alternative materials is prohibitive and may require the use of more skilled labour to install. Most of the materials are relatively
	Craft labor availability	Craft labor is easily available and can be mobilized on a relatively short notice	Moderate scarcity in availability of skilled labor driving increased planning in resource prioritization.	Significant scarcity in availability of skilled labor and/or may involve negotiations with labor unions and using external consultants such as staffing companies.
	Long Lead items	PMT staff is familiar with the vendors' processes and there are liittle or no customs and logistics challenges	PMT staff is unfamiliar with the vendors' processes and the items restrictions include no-return policies, a few customs and logistical challenges, and others.	The procrement process for individual items includes multiple vendors due to inability to meet demand volumes, no-return policies,significant customs or

3.3 Project Complexity Characteristics, Categories and Attributes

The original PTAG Complexity Matrix described complexity based on the characteristics listed in Table 3.2 below. According to PTAG, these characteristics developed from industry experience and literature reviews. The RT 398 Team used the knowledge gained from PTAG's research and carried out their own literature review. This process led to the distinguishing of categories and attributes.

Table 3.2. PTAG's Project Complexity Characteristics

	PTAG Project Characteristics
1.	Type of Project and Criticality of Outcome
2.	Technology or Complexity of design
3.	Frequency of Delivery
4.	Scope/Budget/Schedule (Asset Integrity)
5.	Construction and Seasonal Requirements
6.	Types of Resources Required and Availability of Resources
7.	Operational Interfaces and/or Shutdown Planning
8.	Internal Stakeholder Management Requirements
9.	External Interfaces Management Requirements
10.	Budget / Estimate at Completion

The dictionary makes a distinction between categories and attributes. A category is the place where a product lives whereas; attributes are the common properties that are assigned to a category. By adding details on attributes, we are able to distinguish the characteristics that are enclosed in a category. For example, stakeholder management is distinguished either as internal or external stakeholders. The following sections explain the added attributes for each category.

Table 3.3 lists categories and attributes within those categories as developed from literature review and from the RT 305 Research Paper. Not all categories have attributes as shown in the table below. These attributes and categories were acceptable to the RT 398 Team because of the experience of the SMEs and the thorough nature in which they were developed. The RT 305 Team initially identified 50 complexity attributes. The team used multiple brainstorming sessions, individual interviews and breakout sessions to drive down the number of attributes to 26 with 11 major categories. The RT 305 Team proved these attributes acceptable through industry validation.

The attributes highlighted in green are present in both the PTAG Complexity Matrix and Table 3.3. This shows how the matrix developed from previous validated research. The RT 398 Research respondents also validated the attributes in the feedback sessions.

Table 3.3. Project Complexity Categories and Attributes

Categories	**Attributes**
Project	Strategic importance of project, size, frequency of delivery, impact on organization, commissioning and start-up
Stakeholder management	Internal and external stakeholders
Governance	
Fiscal Planning	
Quality	
Safety and Health	
Legal	Environmental, security, permitting, contracting requirements
Interfaces	Operational interfaces

Table 3.3. (Continued)

Execution Targets	Pace of project schedule, adequacy of project budget with implications of possible cost overruns
Design and Technology	Scope definition, technology maturity, design complexity
Location	Location based constraints pertaining to remoteness, seasonal impacts, number of locations
Scope definition	Goal clarity
Project Resources	Project management team, material availability, craft labor availability, long lead items

The *Project Category* is a type of structural complexity. Attributes such as size and frequency of delivery are quantifiable and interdependent. The larger the project size, the higher the distinct elements and activities that are likely to interact. This increase in activities and resources increases the complexity of the project. This category also assesses a project from the feasibility up through the commissioning and start up (CSU) phase. This is because the strategic importance of a project is a factor in the pre-development phases. Strategic importance informs resource allocation and planning, a project that is vital to mandatory financial gains of a company is strategically important.

Stakeholder Management is a key consideration in the UMM sector. There are several reasons for this; some of them include that UMM sector projects cover large geographical area and affect vast swathes of the environment, that is, air, water and land. The effects may be direct or indirect. The potential effects of such projects leads the project management team to consider the level and likelihood of interaction with various stakeholders. Stakeholders may be a source of painstaking litigation if appropriate steps ate not taken to include them in early negotiations.

Modern challenges associated with globalization led to inclusion of the *Governance Category.* This is because globalization has shifted the degree of coordination between field and corporate offices. Depending on the remote nature of a project or the contractual needs, the PMT team may opt to use unconventional approval methods for requests for information (RFIs) or for other approvals. UMM sector project are in nature global projects. Very few companies have the financial resources to fund exploration and mining needs. This may lead to going further out offshore and to remote on-shore locations. In order to ensure efficient decision-making, the corporate office may delegate a certain level of governance to the field PMT team.

Fiscal Planning is a major factor in the UMM Sector because of the volatile nature of investments in the oil, gas and general mining industries. The volatility is due to the global nature of markets and especially oil prices. This led to the SMEs suggesting the inclusion of this category. Another factor that drives fiscal planning is project duration. A project that spans multiple financial years leads to a higher detail of fiscal planning because of the need to generate consistent and adequate cash flows. If the economy is in a volatile state, there is less certainty with regard to the financial decisions of a company hence any project that spans multiple financial years will need to be weighed with the potential of inadequate scope definition in mind.

The *quality* of subcontractors and vendors is important to the UMM sector because of the global nature or these sectors projects, the remoteness of the locations and the skills specialization required to carry out the projects. There are stringent safety and health regulations associated with these kind of projects. This is part of the nature of dealing with oil, gas and minerals in general. To achieve high quality detail, the subcontractors need experience with similar projects. Depending on the location or remote nature of a site, the presence of these subcontractors and vendors may be limited. Given these factors, the quality of the available vendors affects the value of the vendor contracts and the degree of oversight over the work that they will perform.

The previous section described how the quality of subcontractors affects the quality of work. There are *safety and health* requirements in the UMM sector that surpass requirements in other construction sectors. The hazards include explosions, fires, work on high-pressure lines and machine hazards. These hazards can occur during or post construction. Accidents can occur on well sites as oilfields have a high potential for explosion incidents. These considerations must be taken into account in the earlier stages of planning to avoid potential accidents.

The *Legal* category is broad and includes environmental, permitting, security and contracting requirement attributes. Another aspect of safety and health requirements are the environmental regulations by local, state and national governments. These regulations may vary from one location to another depending on the laws. These are normally regulations on allowable gas emissions, run-off controls and impacts on wildlife. The UMM sector has one of the highest permitting requirements because of the restrictions on emissions, the potential impacts of incidents on the environment, there is also the likelihood that the pipelines might cut across multiple jurisdictions, requiring authorization from multiple jurisdictions. The permits may also be issued against the effects of the construction, for example, a limit on the allowable weights that can be carried on local roads. Security is key to safeguarding investments and boosting stakeholder confidence. Millions of dollars are sunk into exploration exercises in the UMM sector. These exercises may fail to bear fruit. However, in the event that the exploration and geological surveys discover the presence of viable resources, the resource has the potential of giving the investors a return worth their investments and this needs to be protected. The remote nature of most sites is another reason why security is an important attribute of this category. In most scenarios, pipelines that run across remote locations may attract unscrupulous individuals who may desire to tap the pipeline in the most unsecure segment. These realities have forced PMT teams to consider the vast implications of insecurity. Contracting requirements may include competing objectives such as trade-offs between cost, schedule and quality. This scenario may arise if stakeholders are yet to define some of the terms that would inform drafting of the contract.

Operational interfaces refer to the points at which an existing operational facility connects to a newly constructed facility. This is a factor of consideration in the UMM sector because of the nature of the sector to expand and make changes to existing facilities. This is to accommodate technological developments or increase in processing quantities of a plant. New facilities are referred to as green field projects in mining sector whereas expansion projects are typically called brownfield projects.

Preliminary assessment of a project leads the project management team to consider the plausible means of project execution. The *Execution Targets* is dictated by the pace of the project schedule and the adequacy of the project budget. Oil and gas projects often set execution targets to increase the chances that production starts when the market prices are favorable. This rush to meet production goals creates nuances in the pace of the project schedule. The experience of the PMT team allows them to gauge the adequacy of the budget with implications of project cost overruns. UMM sector projects often run into millions of dollars and the implication of cost overruns is detrimental to the project stakeholders. This pushes the team to examine any potential shortcomings of the budget. These attributes are heavily reliant on the competency of the project management team. Also, UMM sector projects have a likelihood of high cost overruns. This is because of the difference between site conditions. There is always a possibility that drilling may be hampered by the presence of hard rock leading to an increase in the amount of money allocated to drilling and other field activities. This is a consideration in budget allocations.

Design and Technology is a major factor in the UMM sector given the reliance on technology. This sector relies on technology because developments promote the ability to extract minerals at a lower cost. The potential of lower costs are dependent on scope definition, technology maturity and design complexity. Scope definition is an attribute of design because this particular attribute refers to the design scope. Research on construction projects has shown that a significant number of projects begin the execution phase with incomplete designs and a low level of scope definition. The ability to determine the potential impact of scope definition during the earlier stages is an indication of project complexity. Technology maturity refers to whether the owner has prior experience with the project technology. This is because technology that has been used for a long time has less faults because it has been tested over multiple projects. Technology maturity is a factor in the UMM sector as journals and researchers publish material on laboratory tested cases and case studies on projects that reap cost and schedule benefits. If the PMT team lacks experience with the technology, this should be taken into consideration during the planning phases.

The remote nature of the *Location* of a potential construction site is another complexity category. The attributes include location-based constraints pertaining to remoteness, seasonality impacts and number of locations. Location-based constraints pertaining to remoteness influences personnel recruitment, material logistics, infrastructure availability for local labor or procurement. In a remote location, there are planning considerations toward construction of infrastructure to access the site; the aim is to ease material and personnel site access. If a construction site is in a location that experiences extended winters, there are hindrances to the delivery of materials and the ability of the personnel to work under conditions of extreme cold. The same situation applies in environments of extreme heat or offshore construction sites. The global nature of projects has led to situations where the design and detailing is contracted out to the most cost effective company. In some cases, these companies may be located miles away from the actual construction site. The presence of separate locations of design and construction is a factor in communication management. There may be lags in the ability of the design team to correspond to the onsite team. These lags may have particularly adverse effects in the UMM sector.

The *Scope Definition* here defers from the scope definition category under *Design and Technology*. This scope definition ties into goal clarity because it refers to a general awareness of the high-level project goals. This is a factor of proper and effective communication between the project team and stakeholders. This attribute is appropriate for the UMM sector because of the presence of multiple stakeholders and the variability in resource availability. Presence of adequate resources is a factor in scope definition because the available resources determine the amount of scope.

The *Project Resource* Category touches on some of the tangible attributes of a project; the project management team, material availability, craft labor availability and long lead items. The experience, size and ability of the project management team to work together is crucial to the success of UMM projects. Material requirements are based on the project specifications. Material availability is a unique to UMM projects because of the remote nature of the sites, the environmental or permitting regulations on required materials or the alternative materials that can be used in the event of scarcity of the primary materials. Craft labor is key to activities such as pipe welding, machine operations and electrical installations on industrial plants. Long lead items are unique to the UMM sector because of modularization and the specialty machinery that is required in these facilities. These items are ordered months in advance to allow ample time for the engineers to design and assemble them. These items can lead to delays when proactive status updates fail.

3.4 Project Complexity Categories and Complexity Levels

Project

The estimated *project size* is a source of complexity because relatively expensive projects tend toward cost overruns. In mining, an example of a simple project is replacement of a water pump; however, construction of a new facility is a more complex mining project. The increase in the number of elements leads to increase in the probability that a change in a portion of the facility will alter the cost of other portions. This knowledge causes the team to view a large project as being more complex. Project size is relative for different companies based on their previous experience with similarly sized project.

Projects that have a high capital expenditure are more likely to exceed the initial allocated budget. The *strategic importance of a project* lies in the value that upper management puts on the project. Maintenance projects are examples of strategically simple projects. Mandatory complex projects are either required by changing regulations, or are critical to the bottom line of a company. The complexity is in the targets that need to be met before the project is complete, the effects that they will have on the ability of the company to pursue other goals and the planning for strategic resource reallocation during the execution.

The *frequency of delivery* is an important characteristic of a project. This is because institutional knowledge is retained in the workforce and the company's database whenever a project is executed. More so, for a project that involves the use of new technology and design. A project carried out five years ago may as well be a new project because the personnel may have changed within that period; the methods of implementation have changed rendering the previous means of execution ineffective. Projects executed on a repeat basis create experts, as the project management team instinctively knows how to execute them and is generally familiar with the unique nature of that type of project. Repeat projects generally have a lower level of complexity. A project of medium complexity lies in between these two, the judgement call is dependent on the project team. The team may consists of few individuals who were present when a similar project was executed by the owner. However, if the majority of the team lacks the institutional memory required there may be a learning curve or failure in sharing that experience. Balancing these efforts generates a moderate level of complexity in a project.

The *impact on the organization* is a characteristic that influences project complexity because of the planning questions that it invokes. The PMT team will need to consider creating new roles and responsibilities, pulling personnel from different projects, and halting budget allocation to other departments for a complex project. A highly complex project has budgetary requirements that may draw resources from another project in the same organization. This relationship creates challenges in planning and allocating resources.

Commissioning and startup can be complex if the operating organization lacks a skilled team to engage with the PMT during the initial project life cycles or during the execution phase. This creates a gap in knowledge transfer. The skilled operations team can offer reliable information on the expected functions of the facility. They are also unable to test the system to the level required post commissioning. A project is considered to have a highly complex startup and commissioning phase if a new operations team is introduced after startup. This is because this team lacked the knowledge transfer from the previous team leading to difficulty in facility management. The owner may fault the facility designers for operation errors even after hand over of the project.

Stakeholder Management

Internal stakeholders are within the owner's organization, that is, health, safety and environmental, operations and marketing but are outside the project team and contractors. The PMT reports to internal stakeholders to meet the internal metrics set by the company. This process of accountability is in the form of meetings, updates and involvement. The higher the number of internal stakeholders, the more cumbersome the process of obtaining approvals for deliverables to move through the organization. The PMT team should manage the interactions and needs of these stakeholders.

External stakeholders are outside the owner's company and outside the project team. External interfaces include the host Government, co-venture partners, community organizations and environmental groups operating in the same area.

Stakeholder management is a source of complexity because of the number of interfaces that are set up to manage their expectations. The need for quantifiable metrics and frequent interactions increases with the number of stakeholders involved. It is also important to keep them informed on the progress of the project and the effect that the project may have on the territory of the different stakeholders.

Governance

Governance refers to authorizing approvals and the duration of receiving proposals, that is, the level of control by the project manager, PMO or corporate office heads. A project has a low level of complexity if the project manager has the authority to release most of the work orders and approve change orders. However, a project is highly complex if work orders and change orders are required to go through multiple levels of authorization. This authorization process should include people in the corporate office such as directors or a board of governors to qualify as highly complex. The project team can use its judgement to determine if the governance category is of medium complexity. This is done by conceptualizing project specific authorization requirements and comparing them to an internal standard of authorization. If the team perceives that there are significant differences in governance, they can assign the appropriate levels of control.

Fiscal Planning

Fiscal planning refers to the strategic planning based on the available cash flows for the project. A complex project requires funding across multiple payment periods. Cash flows and payment periods are dependent on the national and global economy. A simple project that requires a onetime transaction presents ease in planning for accounting and construction purposes. An example of a moderately complex project is expansion project with full funding available but the cash will only be released on a phase by phase basis. A highly complex project has only partial funding available and its construction spans multiple years. This present a challenge as the rest of the funding is tied to profits generated from the existing facility. This dependency is a source of complexity because if the existing facility is unable to meet its financial goals, the proposed facility may fail to launch.

Quality

This is the quality of the suppliers and subcontractors. This is affected by the geographical location of the site, hence the available vendors. It is affected by the contractual requirements such as the quality assurance and quality control measures and the technology and design details of the project. In complex projects, suppliers and sub-contractors may not have experience with a certain design technology. This adversely affects the pool of legible applicants and choices for the project. This sense of constriction is a source of complexity because it creates a dependence on the available suppliers and contractors.

Safety and Health

Health and safety considerations are paramount to the management of projects in the UMM sector. A project is complex if safety management presents a considerable number of unusual challenges and work operations are expected to be significantly dynamic and uncontrolled. A relatively high number of high-energy hazards requiring unconventional safety management methods or regulatory requirements are expected. A project is simple if safety management does not present unusual challenges and work operations are expected to be less dynamic in a largely controlled area; there are no significant high-energy hazards that require unconventional safety management methods or regulatory requirements. A project is of medium complexity if it has moderate environmental impact or regulatory requirements; there are frequent project team interface with environmental regulatory organizations and frequent scheduled environmental inspections are required.

Legal

Environmental considerations are at the forefront of stakeholder concerns. This is especially so with the push to transition from carbon based fuels. The UMM sector depends on extracting raw materials from the environment and releasing by-products into the environment in a more obvious manner than most industries. This has led to the implementation of environmental policies to protect natural resources. These regulations vary from nation to nation and even among different states in the USA. The environmental regulations in a specific location may be more stringent than other states; this necessitates planning for compliance with the regulations. The compliance may take the form of installing more scrubbers on a flue stack to meet the required levels of gas emissions from a coal plant. A project has low complexity if it has minimal environmental impact and requires minimal regulatory interface and environmental inspections to be only conducted upon project completion. A project has a high complexity if it is environmental driven, and detailed environmental management planning and permitting are required, the daily project team interface with environmental regulatory organizations and daily environmental inspections are required.

Security is a source of complexity because UMM projects are located in remote or dangerous areas. This is to protect people from the negative effects of living around potentially hazardous elements and because carbon deposits are generally in remote locations. The remote nature of these locations causes security considerations. This is more so if the surrounding location is subject to political instability. This would mean that the PMT would have to plan for a certain level of security to attract workers to the site. This planning should include contingencies in the case of security failures and subsequent insurance policies. A simple project may be in a remote area but with minimal security concerns being in a politically stable region. However, a highly complex project site is located in an area known for thefts or where site demonstrations are expected. A detailed site security management plan is required and dedicated daily on-site security personnel and surveillance and access system are required. There are also daily project security team interface with local law enforcement authorities and continuous site security checks are required.

Permitting pertains to the number of permits needed, type of permits and their requirements, ease of obtaining them and their impact on the schedule and budget if delayed.

Permitting is dependent on the scope of a project and the location. Permitting is complex if the scope of the project touches on multiple sectors. For example, if a pipeline runs next to a river, the local water board may require a different permit from the land board. In addition, lack of experience in obtaining types of permits is a source of complexity. The PMT team lacks the confidence to anticipate the effects of the permits on the project schedule and deliverables. A large number of permitting requirements may affect the successful on time delivery of a project.

Contracting requirements as they pertain to payment terms, performance guarantees, insurance requirements and delay damages are a source of complexity. A project is highly complex if there are competing objectives between the contractual terms. In this case, the project management team exerts efforts to balance the competing objectives by trying to understand the implications of prioritizing one aspect against another. For example, the client may want a project fast tracked whereas the project team focus is on ensuring that activities are executed safely. This may lead to discussions concerning insurance premiums for safety and performance guarantees.

Operational Interfaces

The consideration of operational interface is unique to brownfield projects and greenfield projects. Greenfield projects are of lower complexity because no shutdown is required and no schedule constraints are anticipated. A project has medium complexity if no shutdowns are required and there are no schedule constraints hence work can be performed unhindered. A project has high complexity if it requires extensive shutdown with active operational interface and complex tie-ins, that is, the project is not within a planned shutdown.

Execution Targets

These are the desired goals for the execution phase. We divided this characteristic into pace of project delivery and the adequacy of the project budget.

The *pace of projects* has implications on the ability to fast track the Front End Loading, round-the-clock work and shift planning. If a project has to be delivered within a compressed period to meet market demands, there are considerations that arise that otherwise would not be considered under a normal schedule. A fast-paced project requires more craft labor and shift planning. Shift planning introduces labor laws and policy considerations. Planning for increased personnel involves a higher budget allocation. A schedule driven project defines time as the core constraint of the implementation process. The aim of a schedule driven project is to achieve to market date as quickly as possible, owners are willing to allocate financial resources to this end. Failures in quality assurance may abound in the pursuit of timeliness leading to rework. A highly complex project has a schedule 20% shorter than the standard industry practice for a comparatively similar project.

The *adequacy of project budget* with implications pertaining to the possibility of cost overruns. The possibility of cost overruns are higher for a complex project because the margin of inaccuracy is higher. This margin is usually non-existent for a project that occurs yearly. The estimate accuracy may be as high as plus or minus half of the estimated cost of the budget.

Design and Technology

Defining the scope in the earlier stages of a project reduces design complexity. Complete front end loading definition is more important for oil and gas projects than other industries. A project is highly complex when there stakeholders who have yet to define the scope to the project management team by the beginning of the FEP stage. A relatively complex project has stakeholders who are unaligned in terms of scope definition. This lack of scope definition may force the design team to consider design alternatives even at the beginning of the execution phase. This will need to considerable contingency planning for the alternative scope.

The personnel and infrastructure needed to deliver the *technology* requirements on a project are a source of complexity in the UMM sector. Organizations that have consistent experience with installing and managing certain equipment, develop institutional knowledge that improves their ability to manage similar projects. However, new technology is a source of complexity because the PMT passes through a learning curve phase that may affect the schedule. To counteract this, the team may opt to engage an external execution team, further complicating the installation of the technology.

Design complexity arises from technology requirements, geographical constraints or human factors such as inexperience with the design. In a simple project, the design is standard or well understood during the assessment phase. However, in a complex project, execution may start by using the preliminary design details. This creates uncertainty in detail design and restricts the execution phase. Field operations may need to commence before the approval of the detailed design. This may lead to scope changes in later phases of construction hence the need for strategic planning and contingency allocations. Design complexity is also from an untested design based on lack of prior experience. The design complexity forces additional considerations in planning and management that may be foreign to the PMT.

Location

Location-based constraints pertaining to remoteness. This refers to the impact on material logistics and infrastructure availability for local labor or procurement. Organizations may need to build infrastructure to access the project site even before the actual project can begin. There is a moderately impact of locational factors on field operations on projects of medium complexity. An example of such a project is a mining project in a remote region where the roads are in a poor state and need repair in order to be more efficient.

Seasonality impacts refers to normal to extreme weather conditions. Extreme weather conditions necessitate planning around the weather events and the subsequent impact. This leads to complexity in shift planning to attain milestones prior to the weather event. A project is considered complex if the weather conditions are expected to change such that the laborers are unable to carry out field construction and site delivery is likely to be impacted. This is possible in regions where there are hurricanes, freezing and excessive heat and snowing conditions.

The *number of locations* during the detailed design phase affects the project team's ability to coordinate and make prompt changes. A simple project has all the detail design in-house whereas a complex project will outsource the design of complex systems or sub-systems. This outsourcing leads to challenges in integrating the holistic facility model prior to construction. This is because the team may lack opportunities to validate the design leading to multiple coordination meetings during the construction phase to resolve issues as they emerge.

Scope Definition

Goal clarity is the extent to which one is able to acquire detailed and concise information about the project. As the PMT seeks information during the initial stages of the project, they are able to carry out preliminary design and planning. In a complex project, the owners may not have clearly defined the objectives. This lack of definition affects the team's ability to plan and design. This effect may be multi-dimensional depending on the quantity of the information is not available. A simple project has clear goals from the onset. The team is free to ask the owners for information and the owners are willing and able to provide relevant information.

Project Resources

The novelty of the project affects the project management team's execution strategy, experienced personnel and the number of on-going projects at the company. The owner staffs a simple project whereas a highly complex project requires the owner to hire professional project management teams to assist in project management. This is a source of complexity because the hired PMT team would need assimilation into the owners' standard operating procedures. With a new team, there is a learning curve during the initial stages and this may adversely affect the schedule.

Material constraints influence complexity where there is limited availability at an optimum price. Above the optimum price, the project management team plans for alternative materials. These materials may cost more and present logistical challenges. Material constraints considerations arise from material shortages, prohibitive costs of some of the required materials and even permitting or regulatory requirements that govern the use of certain materials. The UMM uses some mineral components that may have local regulations depending on the country. There are significant material constraints in complex projects. This can be due to the remote nature of the site location, inadequate infrastructure leading to the site or the lack of suppliers within the vicinity.

Labor constraints affect complexity where the required skilled labor is scarce or when there is limited availability of craft labor at an optimum price determined by the productivity index. Labor constraints manifest in the execution phase of the project. However, potential causes of labor constraints can be identified in the planning phases. A project has a low level of complexity if the required skilled and unskilled labor is easily available based on the scope and knowledge of the work.

Long lead items generically necessitate pro-active expediting by the PMT team. A simple procurement process for a long lead item occurs if the owner or EPC firm has dealt with the vendor before. This familiarity with vendors negates the need for a learning curve/on-boarding process. A complex procurement process would involve having the item pass through multiple vendors before delivery. This occurs if the item requires work input from multiple trades. The complexity surrounding long lead items is dependent on supply chain considerations. If an item is manufactured half way across the world, the chances that regional conflicts may affect delivery are higher.

4. CONCLUSION

This research aimed at validating the PTAG Project Delivery Model with the aim of developing a Fit-for-Purpose Complexity Matrix for the UMM sector. PTAG's experience managing in industrial projects in the UMM sector provided them with a great foundation to develop the project delivery model that was tailored for mining projects.

The literature review revealed presence of research on the definition of complexity and how to measure complexity in the general construction industry and revealed various categories of complexity. There was little available research into complexity in UMM sector projects and examples of the various levels of complexity within these sectors.

CII RT 398 members were surveyed on the accuracy of the categories and descriptions in the PTAG Project Delivery Model. These SMEs had years of accumulated knowledge in project management. They were also asked to rate their own organizations project delivery effectiveness during all phases of construction. These responses were compared against previous CII RT 305's complexity attributes to generate a holistic matrix.

The research showed that PTAG's matrix is valid for the UMM sector. All the characteristics mentioned in the matrix are considered paramount as shown from literature review and the validation by the respondents. Respondents maintained that technology, frequency of delivery, budget, scope, seasonal requirements, stakeholders, resources, operational interfaces and the type of project are relevant project categories. We went further to include the governance, fiscal planning, quality of subcontractors and legal project categories. The added categories are responsive to the dynamic globalized world that are descriptive of these projects. The last piece of this phase of the research was to develop appropriate definitions for the low, medium and high complexity for each category. These descriptions are meant to provide guidance in categorizing projects.

The research revealed shortcomings in the lack of details on the interaction between R project prioritization and complexity. An industry specific tool that will allow project managers to assign resources based on the results of complexity assessment is useful as companies may be in the process of balancing multiple projects at the same time.

Phase II continues the development of the fit-for-purpose handbook that can assist owners and contractors with improving the predictability of project outcomes by establishing a project delivery approach that is specifically tailored for upstream, midstream, and mining (UMM) projects and expand the utilization of CII tools. It may be that our product can be applied more universally to other CII sectors as well. This phase will continue refining the complexity categories and attributes identified in Phase I. It will also investigate various ways to provide relevant CII best practices and tools to the end users (the "golden nuggets") and will leverage, to the extent possible, the efforts of RT-392 (Concierge research team) to identify relevant tools.

The goal of Phase II is to focus on the complexity model product for more mature PMOs by finalizing the complexity criteria along with their definitions, and pilot testing various concepts for developing the "golden nuggets". The pilot tests may involve developing a standard template for capturing the key information, leveraging the expertise of the CBAs, and using academics and/or consultants to assist with the summarization process. Furthermore, we plan to work closely with CII in developing the best information technology platform for hosting this information.

5. RECOMMENDATIONS

Industry experts should aid the academic team in recommending tools that can be used to manage project complexity. Industry experts are familiar with practical implications of complexity and the effective methods of dealing with it. There should be further documented discussions on the attributes that describe complexity in the UMM sector. This should be done together with documented examples of tools and management techniques that were effective in managing that complexity. There is also the added benefit of expanding the understanding of complexity to all civil engineering sectors, not just the UMM sector.

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APPENDICES

Appendix A: PTAG Project Delivery Model

Figure A.1 presents the five-step approach developed by PTAG, Inc., a CII member company and Best Practices Trusted Advisor, to customize mining project execution plans based on the project's complexity and priority ranking. In Step 1, the Project Priority designations range from P1 to P5, where P1 is the highest priority and P5 is the lowest. In Step 2, the Complexity Index ranges from C1 to C4, where C1 denotes the highest level of execution complexity and C4 the lowest. The Complexity Index values are obtained from a set of ten Complexity Index characteristics to which project managers can assign values. In Step 3, the Project Delivery Model (PDM) is determined based on the Project Priority and Complexity Index values. The PDM values range from PDM-1 to PDM-4, where PDM-1 denotes the highest priority/highest complexity level and PDM-4 denotes the lowest priority/lowest complexity level. In Step 4, the Project Stage is defined based on the project phase. Finally, the List of Deliverables is displayed based on the PDM and the defined Project Stage. These deliverables are color-coded as orange, yellow, green, and light green in decreasing order of importance. That is, deliverables in orange are deemed to be required for implementation whereas those in light green are not required unless circumstantially determined otherwise. This five-step project execution plan outlines the various tasks to be performed at each stage of the construction project and can help project managers to monitor the deliverables to ensure that the project stays on track.

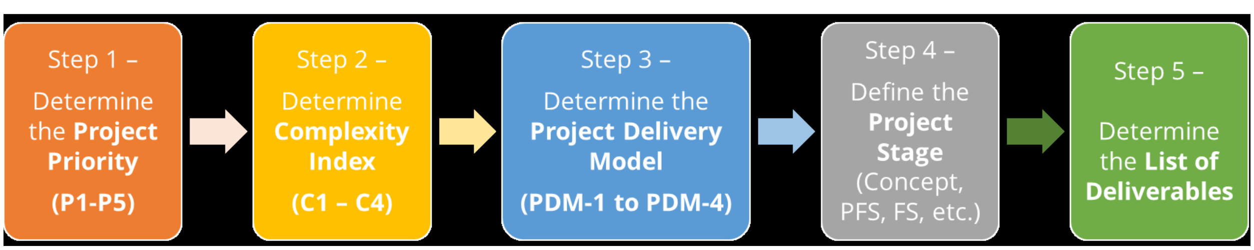

Figure A.1. Five-step project execution approach developed by PTAG, Inc.

Appendix B: CII RT-398 Fit for Purpose Research Project Interview Guide

NCSU eIRB Protocol Number: 24932

Part 1. Subject Matter Experts (SMEs) Interview Guide

This interview study is part of a research study to gain an understanding about the unique circumstances you face in successfully delivering projects in the Upstream Midstream and Mining (UMM) sector within the Construction Industry Institute (CII). Additionally, we want to understand the nature of your organization's project delivery approach in order to see if we can create generic project delivery models for each project type (upstream, midstream, and mining). Ultimately, we plan to identify appropriate CII Knowledge Base tools (e.g., flow diagrams, checklists, and statistical models) that can be conveniently accessed within the project delivery model. This interview provides the research team with important information to help us develop a "fit for purpose" Handbook for the UMM sector by fine-tuning an existing project delivery model. It is anticipated that the interview will take approximately 90 minutes to complete without any monetary compensation. You must be 18 years of age or older and reside in the United States.

Confidentiality Statement:

1. Your participation is voluntary and no IP address will be collected. You can stop participating at any time you may so wish. Moreover, your responses will be collected in a way that they cannot be tracked back to you in any way.
2. You will not be penalized in anyway if you choose to not to answer any question in the interview study.

3. All the files pertaining to this research will be stored in a SharePoint portal maintained by North Carolina State University which include the results from the interviews and focus groups. However, no data can be linked back to any respondent in any manner.
4. You will not suffer risks, discomfort, or inconvenience from your participation.
5. Any data gathered may be used in presentations and publications of professional literature and reports will be anonymous and reported only in aggregated form as no personal identifier information is collected.

As a research study, if you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact the NC State Institutional Review Board (IRB) Office. An IRB office helps participants if they have any issues regarding research activities. You can contact the NC State IRB Office via email at irb-director@ncsu.edu or via phone at (919) 515-8754.

If you have any questions about the administration of the survey, please contact Professor Edward Jaselskis (PI) at ejjasels@ncsu.edu. or Alex Albert (co-PI) at falexal@ncsu.edu.

You can participate in this interview only if you provide your consent having read the instructions above.

Thank you for your time and effort to participate in this interview study.

RESPONDENT BACKGROUND

1. What sector(s) best represent your company's current ongoing projects (select all that apply)
   - Upstream
   - Midstream
   - Mining

- Other (please specify)

2. Do you represent an Owner, Contractor or Service Provider?

3. What is your current job title

4. Provide a brief description of the breadth of your professional experience as it pertains to pre-feasibility, front end planning, execution and operations.

5. How many years of experience do you have in the delivery of capital facility projects?

PROJECT DELIVERY EFFECTIVENESS

6. How would you rate the effectiveness of your company's project delivery approach (1=not very effective to 5=highly effective)?

7. Identify the opportunities to improve projects in your portfolio during each phase.
   - **Pre-feasibility** (business case/need)
   - **Front End Planning** (feasibility, concept and detailed scope)
   - **Execution** (detailed design/procurement, construction, commissioning, turnover)
   - **Operations**

8. Does your company have a Project Management Office (PMO) or projects department or does each project get managed separately by individual teams?

RELATIONSHIP BETWEEN PROJECT COMPLEXITY AND MANAGEMENT REQUIREMENTS

9. Describe the type of project (e.g., replacement pump and driver, installation a new subsea platform and building a new processing facility) that would be considered simple, moderately complex, and highly complex.

10. What are the differences in project management requirements for projects of various levels of complexity (e.g., simple, moderately complex and highly complex projects)?

VALIDATION OF COMPLEXITY CRITERIA FOR ESTABLISHING MINIMUM PROJECT MANAGEMENT REQUIREMENTS

A pilot model has been developed to capture the complexity of projects to establish project management requirements. The model follows a five-step process as follows:

Step 1: Determine the *Project Priority* (highest to lowest priority)

Step 2: Determine *Level of Complexity* (highest execution complexity to least complex)

Step 3: Determine the *Project Delivery Approach* (based on project priority and complexity)

Step 4: Define the *Project Stage*

Step 5: Determine the *List of Deliverables*

The complexity model criteria are reproduced in the table below. As you can see, this model includes 10 characteristics that are assessed for each evaluated project. We would like you to provide your feedback on the suitability of these criteria for the UMM sector.

11. What are your thoughts on these characteristics? Are there additional characteristics that will need to be captured to evaluate projects in the UMM sector or are there characteristics that are redundant that you suggest will need to be removed? If so, please provide your suggestions to improve the model.

12. How appropriate are the descriptions for the complexity type (i.e., level of complexity) across the individual characteristics in the model? Do you have any suggestions on improving the description?

13. Are there any other suggestions that you have on measuring the complexity of projects in the UMM sector?

Characteristic	Level of Complexity				Comments
	Simple	Moderately Complex	Complex	Highly Complex	
Type of project and criticality of the outcome	Maintenance/Sustainable /Value Eng/Quick-win type of project.	Compliance/Operation/ Sustainable type of project required to comply with some HSE requirements.	Compliance/Operation Capital/Growth type of project/required to comply with full HSE requirements or to enable continuous operation.	Strategic or mandatory project required for the long term benefit or survival of the company or dictated by regulatory authorities.	
Technology/Complexity of design	Little or no complexity.	Complexity of design is well understood and team members are well versed.	Known technology within the owner's organization. Some team members are available.	Technology under development or has not been previously applied to the owner's organization.	
Frequency of delivery	Quick-Win projects/Small operations/Maintenance types (3-6 months).	Annual project or repeat project.	Not a repeat but similar to the project done for the owners organization in the past 5 years.	Once in a while project, i.e. not done a similar one in the past 5 years.	
Scope/Budget/Schedule (Asset integrity)	Small project/Quick-win type. It can be standalone or has minimal impact.	Scope/Cost/Schedule issues are well known with minimal impact on other areas.	Technical scope, execution plan, estimate and schedule do not have too much overlap on other areas.	The project may have significant impact on other areas of the organization. Hence interactions required with other operations in the owner's organization.	
Constructional and seasonal requirements	Normal construction environment with very little impact.	Normal construction schedule with little or no tie-ins.	Minimal or short shutdown with normal operational tie-ins and low seasonal impact.	Shutdown situation (L4 or L5 schedule required); round the clock work and shift planning; + external crew required and/ winter works.	
Types of resources required and availability of resources	Small team with little or no matrix support required.	Project can be managed with mostly Project Owner's Team with little additional resources and matrix resources.	Full task force not required. Project can be managed with internal Project Owner's team and some matrix support required and some external Eng Team may be CM team may be required.	Task force required with full matrix support (dedicated project controls teams) + nominated engineering and construction teams required.	
Operational interface or shutdown planning	No shutdown required and the project has no schedule constraints.	Work can be delivered during planned shutdowns with low risk of impact on the current planned shutdown.	Some work can be delivered during planned shutdowns, but it has a high risk of extending the current planned shutdown. (doesn't need a dedicated shutdown).	Requires extensive shutdown with active operational interface and complex tie-ins (i.e. the project is not within a planned shutdown.	
Internal stakeholder management requirements	Very little interaction with internal stakeholders and/or some interaction with third parties.	Some interactions with operations and HSE team (1-2 times a month) to ensure continuity of operations.	Frequent interactions with operations and HSE team (1-2 times a week) to review plans and incorporate changes.	Frequent interactions with internal stakeholders (4-5 times a week) to review, plan and incorporate changes. It requires dedicated resources and full time project controls/contracts administration team.	
External interfaces management requirements	Very little or no external interaction required with EPCM or Construction contractors.	Little interaction with EPCM/external SMEs/Technical advisors/Construction contractors.	Some interaction with external EPCM/SMEs/Technical advisors/Construction contractors/Government/ Communities.	Regular interface management required with external EPCM/SMEs/Technical advisors/Construction contractors/Government /Communities.	
Budget/Estimate at completion time (EAC)	It is a low CAPEX project(The CAPEX value has little impact on complexity factor because it's a procurement type contract).	$1M<x$20M	$20M<x<$100M	>$100M	

Appendix C: CII Research Team

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