META-ANALYSIS FRAMEWORK FOR IDENTIFICATION AND ASSESSMENT OF BEHAVIOR-CENTRIC INTANGIBLE RISK FACTORS IN ENERGY PROJECT PORTFOLIOS

A Dissertation

by

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ABSTRACT

In the oil and gas industry, it has become common to note that projects do not meet their objectives between 50 and 75% of the time, leading to adverse implications on corporate value. The Oil and Gas Authority of the United Kingdom has attributed this phenomenon to events that are nontechnical in nature, or intangible factors. Risks can be both tangible (e.g., design error) and intangible (e.g., behavior), with the emergent intangible dimension creating project complexity.

Project risk management has been an area of academic interest since the end of World War II and is a recognized methodology that enhances the probability of a successful project outcome. Current risk management assessment methods are oriented toward systems that are linear and vary from basic qualitative assessment to complex statistical analysis primarily focused on tangible project factors. Risk profiles vary as a project moves through the development cycle and include a systemic dimension for portfolios of projects. However, the implications of human behavior on project objectives are highly variable and can be “blind spots” for individuals and teams.

The goal of this research was to develop a framework to identify emergent behavior-centric intangible risks and the conditions that initiate them. The proposed framework, intangible risk assessment methodology for projects (IRAMP), utilizes a behavior-centric risk breakdown structure, risk causal factors, and a risk inducement matrix linking risks to the causal factors that precipitate them for each stage of the project development cycle. A metanetwork (i.e., a network of networks) consisting of the interactions among intangible risks, causal factors, human agents, and project tasks was modeled by the commercially available ORA-PRO software to generate network analysis measures.

This research contributes to the field of risk management in several significant ways. First, it introduces IRAMP as a new empirically based framework for the identification of behavior-centric intangible project risk throughout the development cycle. Second, it pioneers the inclusion of behavior-centric intangible risks and the conditions that cause them in a metanetwork construct, creating the ability to use dynamic network simulation models. Network analysis measures are identified for use in quantifying the implications of events and their influence on behavior-centric risks. These quantitative measures identify relationships within the metanetwork and the implications of making modifications. The ability to make the subjective objective enhances the overall effectiveness of the risk management process.

DEDICATION

Dr. Kenneth F. Reinschmidt

1938–2018

An exceptional person, professional, and mentor

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NOMENCLATURE

3D	three-dimensional
CASOS	Computational Analysis of Social and Organizational Systems
CEO	chief executive officer
COO	chief operating officer
CPM	critical path method
EPC	engineering, procurement, and construction
EPM	assistant engineering manager (OilCo)
EPMP	manager of project management (OilCo)
EPPM	project manager (OilCo)
FEED	front-end engineering design
GST	general systems theory
HSE	health, safety, and environment
InSPECT	innovation, social, political, economic, communications, technology
IRAMP	intangible risk assessment methodology for projects
IRBS	intangible risk breakdown structure
JVP	joint venture partner
KPI	key performance indicator
MIT	Massachusetts Institute of Technology
MNA	metanetwork analysis
N/A	not applicable
NASA	National Aeronautics and Space Administration
OE	operations engineering (OilCo)

OGA	Oil and Gas Authority
OII	operations integration and initiation (OilCo)
OM	maintenance operations (OilCo)
OMM	manager of operations (OilCo)
OP	production operations (OilCo)
OS	operations safety (OilCo)
P&ID	piping and instrumentation diagram
PERT	program evaluation and review technique
PESTLE	political, economic, social, technological, legal, environmental
PMI	Project Management Institute
PSF	performance shaping factor
QA/QC	quality assurance / quality control
RACI	responsible-approve-comment-inform
RBS	risk breakdown structure
RIM	risk inducement matrix
SME	subject-matter expert
SNA	social network analysis
SPECTRUM	sociocultural, political, economic. competitive, technology, regulatory/legal, uncertainty/risk, market
SRA	Society for Risk Analysis
STEEPLE	social, technology, environmental, economic, political, legal, ethics
SWOT	strengths, weaknesses, opportunities, threats
T&Cs	terms and conditions
TECOP	technical, environmental, commercial, operational, political

VIER	validation, identification, evaluation, and recommendation
VUCA	volatility, uncertainty, complexity, ambiguity
WBS	work breakdown structure

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CHAPTER I

INTRODUCTION, PROBLEM STATEMENT,

RESEARCH HYPOTHESES, GOAL, AND OBJECTIVES

Introduction

The concept of risk has a ubiquitous presence in all facets of human endeavor, from investing in the stock market to choosing a profession to considering the weather when planning an outdoor event or vacation. In Greek mythology, the beginning of the universe is said to have resulted from a game of chance played by the brothers Zeus, Poseidon, and Hades regarding dominion. Who would rule the heavens, the seas, and the underworld (Bernstein 1998) denotes the tangible outcome of the event. However, the implications of behaviors, such as Poseidon's jealousy and plotting against the rule of Zeus, are not easily quantified. In a more mortal dimension, human agents within businesses make investment decisions under uncertainty on a regular basis as they select specific projects to comprise a portfolio that will enable the firm to meet its strategic goals. The business environment in which these organizations operate and execute projects is complex (Elonen and Artto 2003) and turbulent (William and Rūta 2017); adding to this complexity are human behaviors and mental frameworks that are dynamic nonlinear systems (Afraimovich et al. 2011). Therefore, the more effective an organization is at identifying and holistically addressing uncertainty, the more likely it is to achieve its objectives (Hillson 2014).

When it comes to investment, the energy sector is the most intensive and volatile industry in the world (Davis 2020; Schroeder and Jackson 2007), with 2017 capital expenditure reported at $714 billion (Varro 2018). The environment in which this investment takes place is one where stability and certainty are rare while complexity and ambiguity dominate the landscape

(Kraaijenbrink 2019). Projects can take many years to move from conceptual planning to initial operation, subjecting them to a myriad of risks. The Project Management Institute (PMI) has utilized the term “progressive elaboration” to describe the increasing level of detail required as a project progresses though its development stages (PMI 2017); changes in the internal and/or external project environment during this evolution can create unforeseen uncertainties that can impact project objectives. According to industry surveys done by management consulting firms Deloitte (Deloitte Center for Energy Solutions 2015) and Ernst & Young (EY 2014), fewer than half of projects in the energy sector meet their objectives, and more than two-thirds of executives are not confident that their organizations are experiencing optimal financial returns. An effective risk management process identifies and addresses project uncertainties and ambiguities and contributes to the effective delivery of project objectives (Hillson et al. 2006). This level of project performance in the energy sector creates the impetus for further investigation into current risk management methodology.

Project performance is measured in terms of meeting objectives and is influenced by both hard (i.e., tangible) and soft (i.e., intangible) factors. Rolstadås et al. proposed a five-aspect qualitative framework for assessing project performance that highlights the importance of risk management using both hard (structure and technology) and soft (culture, interactions, social relations, and networks) aspects (Rolstadås et al. 2014). PMI has defined risk as “an uncertain event or condition that, if it occurs, has a positive or negative effect on a project’s objectives” (PMI 2017). Although risk can be either a threat or an opportunity, it generally carries a negative connotation (Chapman and Ward 2003). Current project risk measures tend to focus on the tangible factors that have a direct impact on project success in terms of cost, schedule, scope, and quality (PMI 2017). However, organizations and their project teams can face issues from other sources, such as internal politics, culture, and agents' adaptive behaviors (Rasmussen 1997). For example, these dynamics can manifest themselves in resistance to initiatives that threaten vested interests and power or behavioral responses steeped in organizational values, beliefs, and accepted norms (Ancona et al. 1999). The ability to assign a risk exposure from politics, culture, or the interpersonal conflicts stemming from them is much more difficult to quantify and "require[s] a greater degree of subjectivity and intuition" (Basu 2017).

Projects by their nature are dynamic, complex, sociotechnical systems (i.e., interactions between human agents and technology) consisting of a multiplicity of highly interconnected components (Baccarini 1996; Carley et al. 2007). Project complexity increases significantly as the number of elements, interactions, and interdependencies in the system expands (Elonen and Artto 2003). Accurately addressing issues that arise can be arduous because of the cause and its' resulting effect not occurring in time and space proximity (Repenning and Sterman 2001). Compounding this are the nonlinearities inherent in human behaviors, where a wrong attribution of cause can give rise to what Roth and Senge described as "wicked messes" (Roth and Senge 1996). These "wicked messes" can be traced to human judgement being subject to systematic errors, where the need to carefully analyze information is traded against the pressure to make a timely decision (Skitmore et al. 1989). Behavioral manifestations, being noncorporeal, are difficult to measure and can be "blind spots" for project teams and other stakeholders (Dargin 2013); consequently, in this research, they are referred to as "behavior-centric intangible risks." Therefore, project risk identification and analysis require a multidisciplinary perspective.

The Cambridge English Dictionary has defined intangible as "influencing but not able to be seen or physically felt." In the literature, the topic of intangibles has predominately focused on intellectual capital (O'Donnell et al. 2003), intangible asset valuation (Nichita 2019; Saunders and Brynjolfsson 2016), and emergent technology or regulation (Foxon et al. 2005). Demmel and Askin proposed the identification and inclusion of value-adding intangibles (e.g., increased flexibility, reduced lead times, etc.) when making investment in technology for manufacturing processes (Demmel and Askin 1992). In his book *Intangibles: Management, Measurement, and Reporting*, Baruch Lev defined intangible assets as “non-physical sources of value (claims to future benefits) generated by innovation (discovery), unique to organizational designs or human resource practices” (Lev 2001). However, literature regarding intangible risks in projects is scant and what exists tends to focus on discrete topics. Hofman et al. defined intangible risk as “emerging or negative phenomena,” which includes interpersonal conflict and lack of appropriate resources (Hofman et al. 2017). Others have highlighted the quality of management (Jonas et al. 2013), unclear roles and responsibilities (Sanchez et al. 2009), preoccupation with personal interests (Beringer et al. 2013), unclear or conflicting priorities (Blichfeldt and Eskerod 2008), lack of end-user involvement, and unclear objectives (Morris 2008). Thamhaim and Wilemon addressed conflict caused by interpretation of procedures on the basis of cost and/or schedule estimates (Thamhaim and Wilemon 1975). This list of intangible factors can be divided into two interrelated groups, behavior-centric factors (interpersonal conflict) and causal factors (unclear or conflicting priorities); however, the literature lacks a clear distinction between the two.

In aviation accident investigation and processing plant operations safety (e.g. chemical, refining, etc.), human actions are considered the highest contributor to failure due to the complex interaction of humans and technology. Because of this inherent complexity, these sociotechnical interactions are viewed as nonlinear systems or “causal webs” (O'Hare 2000; Rasmussen 1997). Rasmussen recognized the intangible implications of behavior in the context of safety risk in process plant operating environments. His conceptual framework, the dynamic model of safety and system performance, is a troika of constraints (economic, workload, and performance) with behavioral reactions within these boundaries exhibiting "Brownian movements." These movements are the result of interactions among management expectations of efficiency, the implications on workload, and employee response to this potential increase in effort. Rasmussen referred to these interactions as "gradients." However, he recognized, "the problem is that all work situations leave many degrees of freedom to the actors for choice of means and time for action even when the objectives of work are fulfilled and a task instruction or standard operating procedure in terms of a sequence of acts cannot be used as a reference of judging behavior." Rasmussen went on to say that "we need a framework for identification of the objectives, value structures, and subjective preferences governing the behavior within the degrees of freedom faced by the individual decision maker and actor" (Rasmussen 1997). These interactions or gradients can be conceptualized as a network of interacting networks within an organization.

Currently, there is not a quantitative framework available to identify and analyze intangible factors or "subjective preferences governing behaviors" in projects. In this research, the framework used to assess a network of networks is referred to as metanetwork analysis (MNA) and is an extension of traditional social network analysis (SNA) (Carley et al. 2007). SNA has been applied to construction projects to identify opportunities to enhance project effectiveness within the broader organizational context by enhancing knowledge transfer and collaboration in project teams (Chinowsky et al. 2008). However, SNA is limited to the assessment of network interactions among individuals (agents) or social groups. MNA removes this constraint and extends the analytical capability to multiple networks, providing a means for a comprehensive assessment of project network elements and interactions (Carley 2002). The metanetwork technique provides the framework to address the analytical gap in Rasmussen's conceptual model by leveraging mathematically robust social network measures. The metanetwork used in this research is based on the conceptualization of a project as the interactions among human agents, tasks, behavioral risk factors, and risk causal factors.

Problem Statement

Why do projects fail to meet their objectives? The challenge of increasing project delivery effectiveness is not limited to the energy sector. The Construction Industry Institute reported only 5.4% of 975 studied projects to meet their targets (Zhu and Mostafavi 2017). In a Global Oil and Gas Intelligence interview with Edward W. Merrow, founder and chief executive officer (CEO) of Independent Project Analysis (an industry-leading benchmarking consultancy), Merrow made the following observation regarding the cost and schedule performance of oil and gas megaprojects (those costing more than $1 billion): "Almost four-fifths of the projects, over three-quarters of the projects, have to be classified as failures. It's very disappointing, and this is counting projects over the last decade" (Haidar 2014). Flyvberg et al. found that many project failures are caused in part by human behaviors (Flyvbjerg et al. 2009), and the Oil and Gas Authority (OGA) of the United Kingdom has attributed many of the reasons for projects not meeting expectations to events that are "non-technical in nature" (OGA 2017). In light of the capital intensity of the energy sector, if effectively addressing nontechnical-in-nature events can increase project spending efficiency by 1%, the overall energy sector cost in 2017 could have been reduced by more than $7 billion. Therefore, the pursuit of an answer to the question of why projects do not meet their objectives leads to the central hypothesis that incorporating the identification and assessment of human behaviors into the risk management process will enhance project performance.

Research Hypotheses

Projects and project portfolios can be conceptualized as complex and dynamic sociotechnical systems (Carley 2002). This research utilizes the definition for a complex system from the Society for Risk Analysis (SRA): "A system is complex if it is not possible to establish an accurate prediction model of the system based on knowing the specific functions and states of its individual components." Complexity has been defined contextually as "a causal chain with many intervening variables and feed-back loops that do not allow the understanding or prediction of the system's behavior on the basis of each component's behavior" (Aven et al. 2018). In light of this, the current approach to project risk management does not provide a robust framework for assessing complex behavior-centric risk factors or the events that cause them.

Hypothesis 1

The development of a framework for use in identifying and prioritizing behavior-centric intangible risks will enhance the overall quality of risk management for project and project portfolios.

Projects by their nature are complex systems and have multiple interrelationships (Carley 2002; Zhu and Mostafavi 2017) that create "dynamic complexity"—a term used to describe a system that is subject to time delays, feedback loops, and nonlinear behavior (Sterman 2000). This nonlinear behavior emerges from the "human-oriented social aspects" of the particular system under consideration (Roth and Senge 1996). These human behavior–induced complexities are difficult to quantify and can be referred to as intangible factors. These intangible factors can influence a project team's ability to meet its objectives and, therefore, are considered to be project risks (Bankolli and Jain 2014).

Hypothesis 2

A quantitative approach to characterize behavior-centric intangible risks, along with appropriate measures, increases the likelihood of projects meeting their objectives.

Currently, no empirical information, tools, or measures exist in the literature regarding the identification, characterization, and quantification of behavior-centric intangible risks during the project or project portfolio life cycle. The current literature regarding behavior-centric intangible risk is limited and generic in nature, linear in assessment, and confined to particular aspects of individual projects, with no holistic assessment of the implications in projects or portfolios. Therefore, an analytical framework and empirical assessment are needed to better understand the implications of behavioral intangible risks.

Hypothesis 3

A framework and quantitative approach developed for projects and project portfolios can be applied to each stage of the project development cycle and can enhance overall risk management effectiveness.

This leads to the overarching research question: Would the development of a framework to identify, assess, and quantify behavior-centric intangible risks enhance project and portfolio risk identification and assessment? The scope of the research to address this question is shown in Figure 1. The subject areas labeled “Not in Scope” are addressed in this research; however, a detailed assessment of these topics is not feasible.

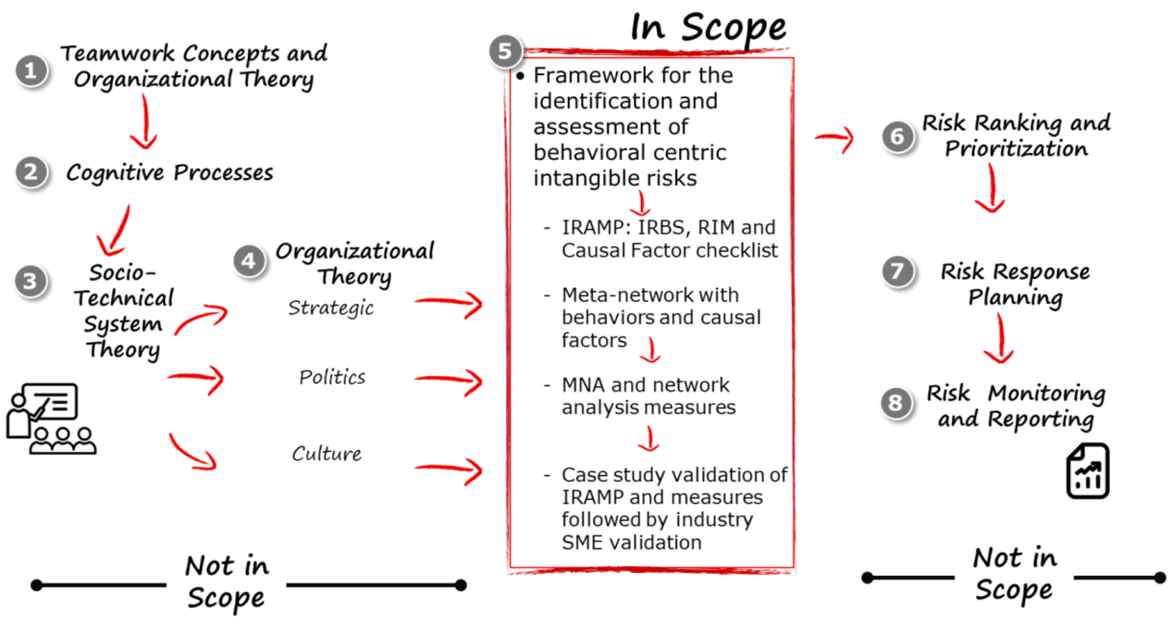


Fig. 1. Scope of research.

Research Goal and Objectives

The goal of this research was to develop and validate a rigorous and user-friendly framework to identify behavior-centric intangible risks and the conditions that initiate them throughout the project development cycle. The proposed framework—intangible risk assessment methodology for projects (IRAMP)—includes a behavior-oriented intangible risk breakdown structure (IRBS), a checklist of potential risk causal factors, and a novel risk inducement matrix (RIM) to link risks to the causal factors that precipitate them. The metanetwork was developed using existing project documents (organization charts, responsibility matrices, etc.) and information from project workshops (RIM, etc.). Using ORA-PRO, a commercially available MNA software package, network analysis measures were generated to assess potential organizational enhancements to address behavior-centric risk factors and their causal factors. The juxtaposition of simulation results to workshop outcomes was acknowledged to possibly expose inconsistency or bias. A case study based on an active project portfolio of an international energy firm served as the basis for validation of the research.

To achieve this goal, this research endeavored to accomplish the following objectives:

(1) Formulate an analytical framework that can be used in project risk workshops to effectively identify and assess behavior-centric intangible risks in projects and project portfolios. This framework will be integrated into existing risk management processes for each stage in the project development cycle.

(2) Identify appropriate analytical tools and network measures of centrality (e.g. betweenness, cognitive demand, etc.) to quantify behavior-centric intangible risks. These measures will be used to provide insights regarding potential organizational or procedural modifications for performance enhancement.

(3) Empirically validate the proposed tools and measures in an active portfolio of projects for an oil and gas corporation and provide specific recommendations for mitigating identified risks.

In 1995, during a review of project performance, Martin Cobb, an employee of the Treasury Board of Canada Secretariat, asked a question that has become known as Cobb's paradox: "We know why projects fail; we know how to prevent their failure – so why do they still fail?" (Carl and Freeman 2010). Albert Einstein is credited with the proverbial statement, "We cannot solve our problems with the same thinking we used when we created them" (Connolly and Rianoshek 2002). Perhaps the first step to addressing Cobb's paradox and Einstein's proverb is to explore the assertion that "the intangible is gaining ascendancy over the tangible" (O'Donnell et al. 2003). Identifying and quantifying the intangible and tangible network elements and their interdependencies can enhance project and portfolio outcomes. This research is the first empirically based step into the arena of intangible risk assessment in oil and gas projects and project portfolios.

Dissertation Outline

This dissertation comprises eight chapters. Chapter I highlights the motivation, goal, objectives, and contributions of the research. Chapter II outlines the research methodology. Chapter III reviews the literature related to behavior-centric intangible risk in projects and project portfolios to identify the gaps to be accounted for in formulating the new framework. Chapter III discusses the project and portfolio context; project and portfolio risk; intangible risk assessment in projects and portfolios; and systems, networks, and MNA. It also provides a chapter summary and the point of departure for this research. The conceptual framework for behavior-centric intangible risk assessment is detailed in Chapter IV. In this chapter, the foundational models developed by previous researchers (Maier 1998; Rasmussen 1997) are extended to projects. Chapter V introduces the IRAMP, including the IRBS, the causal factor checklist, and the RIM. Chapter VI discusses MNA, the system model, and network analysis measures and concludes with results from a workshop of industry subject-matter experts (SMEs). Chapter VII presents a case study of a project portfolio to illustrate the methodology developed for this research. The case study identifies the intangible risks and potential causal factors, develops the IRBS based on actual projects at various stages of development, and validates the results with working teams and senior management. Chapter VIII summarizes the major findings of this research, the contributions to industry, the limitations of the research, and areas for future study of intangible risks.

CHAPTER II

RESEARCH METHODOLOGY

Summary

The methods and workflow used in this research to develop the IRAMP and confirm the hypotheses are presented in this section. The specific methods include structured interviews, survey, literature review, workshops, conceptualization, case study, and analysis. The author's role was twofold, first as an advisor to the management team of the oil and gas corporation (OilCo), as well as their representative on the organizational review team, and second as an active researcher. Table 1 and Figure 2 provide a summary of the methods and workflow used in the development of the IRAMP. Figure 2 details the sequence of activities to accomplish the research objectives and address the research hypotheses.

Table 1. Research methods summary

	Research method
IRAMP component	
(a) IRBS	Semistructured interviews, survey, workshop
(b) Causal factor checklist	Literature review, workshop
(c) RIM	Workshop
Metanetwork development	Conceptualization, literature review
Test hypotheses, IRAMP framework, and Metanetwork development	Workshop
Validation	Case study, analysis

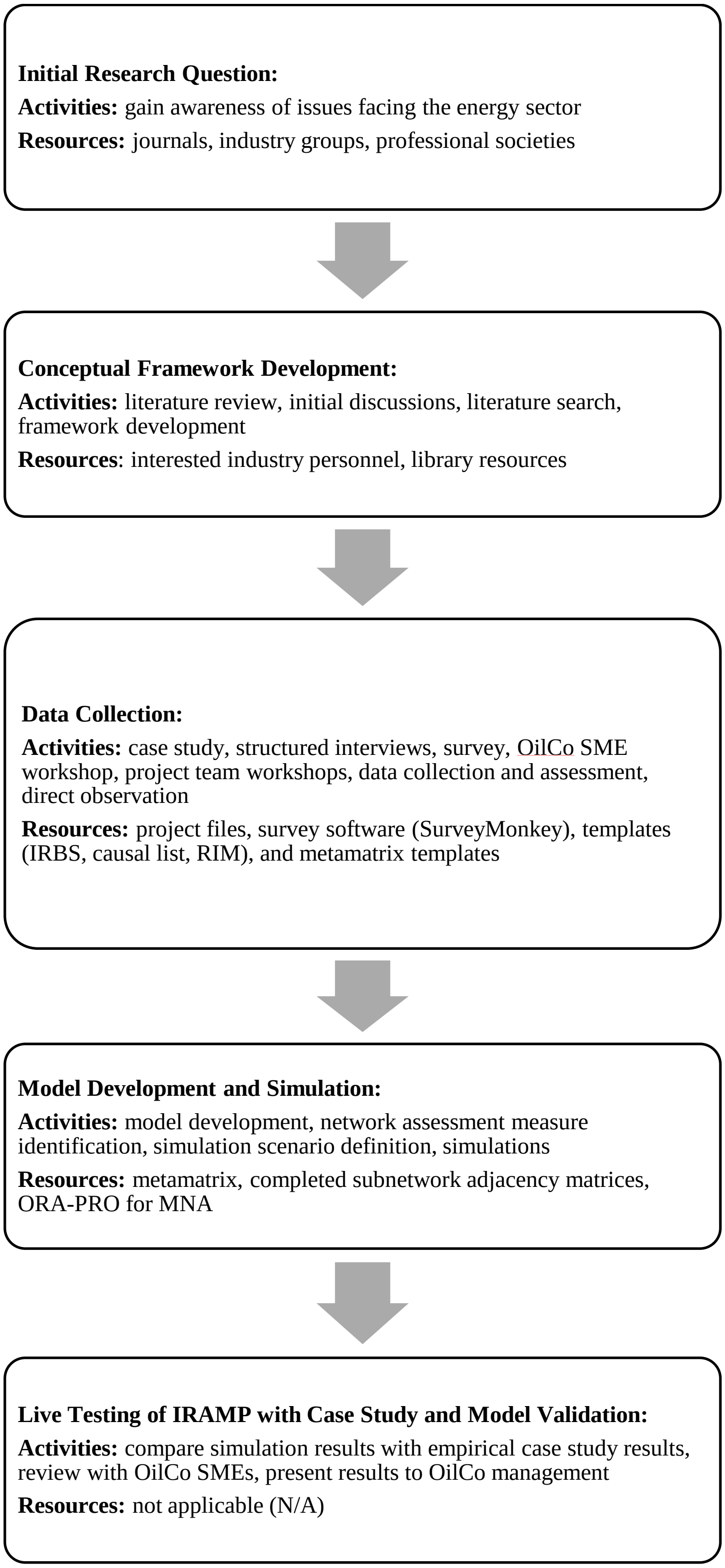


Fig. 2. Research workflow.

Conceptual Framework Development

Projects and project portfolios can be conceptualized as complex and dynamic sociotechnical systems (Carley 2002). The evolution of the conceptual basis for this research began with the utility of analytic reductionism in complex systems and progressed through the application of a system-of-systems approach. Chapter III describes the evolution of the conceptual framework used in the research

Purpose of Data Collection—Template Completion

Intangible Risk Breakdown Structure

A risk breakdown structure (RBS) is a hierarchical framework that consolidates identified project risk events into different levels similar to a decision tree structure (Hillson 2003). However, there is not broad consensus on how to develop an RBS, the definition of risk categories, or how to include qualitative/quantitative information in the structure (Rasool et al. 2012). The IRBS utilizes a similar hierarchy; however, because it is behavior-focused, it must be aligned with the behavior-centric factors unique to the organization within which the project is being sponsored. In this research, this was achieved by the use of initial interviews to identify the behavior-centric uncertainties, a survey to validate the interview results, and a workshop with management (or their delegates) to present the results and a forward plan for approval. Chapter V details the IRBS development, and Chapter VII provides details of the IRBS application for this research.

Causal Factor Checklist

Causal factors are occurrences that can affect human behavior and initiate a sequence of mental and emotional reactions (behavior-centric intangible risks) as people attempt to make sense should unplanned changes or issues arise in the working environment (Isabella 1992). A standard listing of these factors does not exist in the current literature; however, many factors are addressed on an individual basis (e.g., misaligned priorities). A literature review was used to develop a general checklist. Causal factors are unique to the project context (Haji-Kazemi et al. 2015) and were identified using a workshop format. Chapter V details the causal list development, and Chapter VII provides details of the application of the causal list for this research.

Risk Inducement Matrix

The RIM is an adjacency matrix created by combining the most detailed level of intangible risks from the IRBS and the list of risk causal factors. The RIM provides a way to address system complexity by providing a means for mapping multiple events interacting with multiple risk factors. The RIM provides a structured approach to address the arduous topic of behavior. The matrix was completed in the same workshop as the causal factor identification. Chapter V details the RIM development, and Chapter VII provides details of the application of the RIM for this research.

Metamatrix

Behavior-centric intangible risk in projects and project portfolios can be conceptualized as a dynamic network of networks made up of the following entities: people involved in the project throughout the development cycle or stages; deliverables or tasks; behavior-centric intangible risk factors; and events or conditions that can cause the risk to occur. The metanetwork has been demonstrated to be a useful framework for representing the interactions among various networks (Carley 2002; Li et al. 2015; Merrill et al. 2007; Wang et al. 2018; Zhu and Mostafavi 2017). The fundamental building blocks of networks are nodes that can represent tasks, agents, information, resources, etc. in organizations; their interactions are referred to as links. An advantage of this approach is the ability to analytically quantify and visually display complex behavioral interrelationships (McCulloh and Carley 2008). Human behaviors and mental frameworks are themselves dynamic nonlinear systems (Afraimovich et al. 2011).

The interactions among the aforementioned entities define the networks within the metanetwork. Each of these interactions is quantified using adjacency matrices. The adjacency matrix input is unique for each project and requires project stakeholder input to complete these templates. However, project stakeholder time is limited, and workshops can consume hundreds of man-hours per event. The researcher completed many of the adjacency matrices using existing information (e.g., responsibility matrices, work breakdown structures [WBSs], organization charts, etc.) and held several informal meetings with key project stakeholders to finalize the metanetwork. A commercially available software simulation package was used to simulate the metanetwork. Analytical network measures resulting from this computational model were used to assess the key nodes to identify opportunities for improvement. Chapter VI details the metanetwork development, and Chapter VII provides details of the application of the metanetwork for this research.

Data Collection Methods

In this phase of the methods used for data collection, IRAMP development and validation and completion of the required templates were the focus. Each method (e.g. interviews, surveys, workshops) is described in the order of occurrence. A step-by-step approach is presented in Chapter V.

Semistructured Interviews

An interview is one of the most important sources of information gathering in a case study research context. Interviews are most effective when they take the form of a casual conversation as compared to a structured question-and-answer session (Yin 2014). In this research, a semistructured face-to-face interview approach was used. An interview outline was developed to ensure that all aspects of the project process were appropriately addressed. Each interview was performed by two or three members of the organizational review team. These teams were made up of OilCo external consultants and internal advisors, including the researcher. Prior to the interviews, the organizational review team had discussions with executive management to review relevant technical documentation and were given access to relevant project information.

The interview agenda was provided to all interviewees one week prior to the interviews. The agenda used for these interviews was as follows:

(1) Introduction to the project

(2) Discussion on improvement areas, in particular:

- Project management framework
- Key processes
- Organization and communication
- Capabilities

(3) Next steps

The interview started with a brief explanation of the purpose of the organizational review and the goal of identifying opportunities to improve project delivery in two areas: hardware (structure and processes) and software (capabilities and communication). Specific questions were developed for each of the discussion improvement areas based on the discussions with executive management and were framed as “how” questions (e.g., “How does the current project management framework support or hinder effective project delivery?”), followed by “why” questions (e.g., “Why does this occur?”). The final portion of the interview was intended to provide the interviewee with the next steps in the organizational review process and to alert them that all feedback would be anonymous.

All members of the interview team took notes, which were consolidated during a postinterview debrief session. Additional information regarding the interviews used in the case study can be found in Chapter VII.

Survey

The behavioral topics raised during the interviews were categorized and compared to existing frameworks in the literature. A recognized framework that closely aligned with the interview feedback was selected and presented to executive management with the recommendation to survey the broader stakeholder population. This information was reviewed by the OilCo SMEs prior to the release of the survey to the broader population. The survey consisted of 20 questions and utilized a Likert scale with the following response categories: (1) strongly disagree, (2) disagree, (3) neither agree or disagree, (4) agree, and (5) strongly agree. The survey was done electronically utilizing SurveyMonkey. The details regarding the survey questions and results can be found in Chapter VII.

Workshops

Workshops were utilized to gather information and as a means of validation using a consensus approach. The researcher scheduled and facilitated 12 workshops: 9 with project teams, 1 with OilCo SMEs, 1 with OilCo management, and 1 with industry SMEs. The researcher’s role included development of preread information, email and phone correspondence with workshop participants, developing presentations for the workshops, developing scoring sheets, noting suggestions provided by the participants during the sessions, data collection, data analysis, and providing any recommendations based on the data. The locations for workshops varied; the OilCo workshops took place in various OilCo locations, and the SME validation session was held in Houston, Texas, in a conference room in one of the participating company's headquarters. The agenda topics for the OilCo workshops were as follows:

(1) Summary of progress

(2) Overview of IRBS and causal factors

(3) RIM completion

(4) Review of feedback

(5) Discussion

(6) Wrap-up

Subject-Matter Expert Workshop

The purpose of the OilCo SME workshop was to review the IRBS, causal factor checklist (from literature and interviews), and metanetwork for completeness and endorsement. Dialog among SME representatives from all stakeholder groups proved foundational for achieving consensus. In the workshop, the IRBS and causal factor checklist were discussed in the context of project development. Any changes to the IRBS or causal factors were required to have been supported by the SMEs and documented. The final step was for the SMEs to formally validate the IRBS and causal factors to be used in the workshops with project teams and other stakeholders.

In the workshop, the researcher served as the facilitator and started by providing a summary of the IRBS and the causal factor checklist, as well as providing the context for how the information would be used in the RIM and the metamatrix. Next, the IRBS Level 1 risks were reviewed, discussed, and agreed on. After agreeing on the Level 1 risks, each of the Level 2 risks was reviewed, discussed, and agreed on. The final step in the IRBS validation was a final group discussion to ensure that all SME feedback had been addressed and that all SMEs were in support of moving forward with the IRBS. The causal factor checklist review followed a similar procedure.

Project Team Workshops

The project team workshops were attended by members of the project team, as well as key stakeholder group representatives, and were facilitated by the researcher. In the first session, the project teams presented a brief summary of the project and spoke to what the project team felt went well and what needed improvement regarding the interactions among all the stakeholder groups. When a project team completed its presentation, brief time was given for clarifications.

The second session in these workshops was for completion of the RIM by the project team and stakeholder representatives. The RIM (Table 2) comprises five work templates, one for each of the behavior-centric intangible risks. Each of the behavior-centric work templates was completed in two steps. First, the project team and stakeholder representatives commented on the presence or absence of the risk factors in the project. Once complete, those risk factors were highlighted in the adjacency matrix (x-axis), and the causal factors were identified (y-axis). If warranted, a short reason was entered in the matrix. Once all of the work templates were complete, the researcher summarized the results, and a final review was made during the wrap-up session of the workshop. Usually, there was a coffee break between the final session and the wrap-up to give the researcher time to consolidate the results. During the wrap-up, there was a chance for final discussion and clarification, and then final endorsement was received by the attendees.

Table 2. Example of RIM for project team workshops

Step 1: Which is more prevalent?

Yes/no	Absence of trust	Yes/no	Presence of trust	Comments
Yes	Conceals weakness and mistakes	No	Admits weakness and mistakes	
Yes	Hesitates to ask for help or provide constructive feedback	No	Asks for help and provides constructive feedback	
No	Jumps to conclusions about intentions and aptitudes of others without trying to clarify them	No	Accepts questions and input about their activities	
No	Fails to recognize and tap into others' skills and experiences	No	Gives others the benefit of the doubt	
No	Wastes time and energy managing their behaviors for effect	No	Appreciates and taps into others' skills and experiences	
No	Holds grudges	No	Focuses time and energy on important issues not politics	
Yes	Finds reasons not to engage meaningfully	No	Gives and accepts apologies without hesitation	
		No	Finds reasons to engage meaningfully	

Step 2: What causes the behavior and what is a leading indicator?

Causal events/behaviors	Conceals weakness and mistakes	Hesitates to ask for help or provide constructive feedback	Finds reasons not to engage meaningfully
Lack of clearly defined goals and objectives	x		x
Lack of active management support			
Improperly defined/agreed priorities	x	x	x
Poorly defined roles and responsibilities			
Inadequate or vague requirements (e.g., scope)			
Insufficient organizational structure for scope of work		x	
Culture (punitive, insecure)	x		
Ineffective decision making			x
Key stakeholder misalignment			
Contradicting interpretations of internal policies and procedures	x		
Inappropriate risk tolerance			x
Ineffective communication		x	x
Inability to change or accept change			
Meeting key stakeholder expectations	x		
Inadequate review processes		x	

Management Team Workshop

The final OilCo workshop was held with members of senior management from the stakeholder groups and was facilitated by the researcher. The researcher sent out the agenda, IRBS, causal factor checklist, and RIM to preread two weeks prior to the workshop, which was held in OilCo's corporate headquarters. To start the meeting, the researcher presented an update on the overall organizational review and the workshops completed to date. The next step was to provide an overview of the IRBS and causal factor checklist, reminding the management team of their endorsement by the OilCo SMEs they had appointed, as well as the project teams. This workshop was meant to provide the management team the opportunity to provide its perspective and compare its feedback with that of the project teams. The time available with senior management is usually constrained because of their other commitments, as was the case for this workshop. To accommodate this time constraint, instead of the entire group working through the entire set of RIM worksheets (like the project teams did), five groups were formed, and each worked through one of the RIM worksheets. Once finished, each subteam reported its results back to all the attendees. After each group presentation, the researcher facilitated a discussion and obtained final management team consensus on each of the topics. The researcher entered the results from each working team into a prepared spreadsheet after each team feedback session to compare the management team results to the project team workshop results. The comparison became the basis for the final discussion session and wrap-up. The detailed results are available in Chapter VII.

Methodology Live Testing—OilCo Case Study

The goal of the case study was to assess IRAMP's robustness in the context of a real-world project / project portfolio environment. A case study in a live setting with project teams reacting to real-time changes in the environment lent itself to the study of behavior-centric intangible risks and their causal factors. OilCo is an energy firm having company-operated (operated by OilCo) and non-company-operated (operated by other firms) assets in its global portfolio. Project delivery performance was not meeting executive management's expectations regarding cost and schedule performance. The results of the case study are detailed in Chapter VII.

Validation by Industry Subject-Matter Experts

The research hypotheses detailed in Chapter I were tested in a workshop with a panel of highly experienced industry SMEs. This session was attended by 10 individuals with more than 300 years of combined project- and operations-related experience. To provide the broadest possible perspective, the energy industry sectors represented were upstream oil and gas; midstream transportation and processing; downstream refining and chemicals; engineering design and engineering, procurement, and construction (EPC); global project management consultancy; and fabrication and construction contracting.

The researcher provided participants with a summary of the presentation by email to preread two weeks prior to the workshop and addressed preworkshop queries in phone conversations. The researcher was both presenter and facilitator for this workshop; the agenda is shown in Figure 3. In order to maintain the schedule, the attendees were asked to save questions until the end of each of the agenda items, at which point time was provided for questions and discussion.

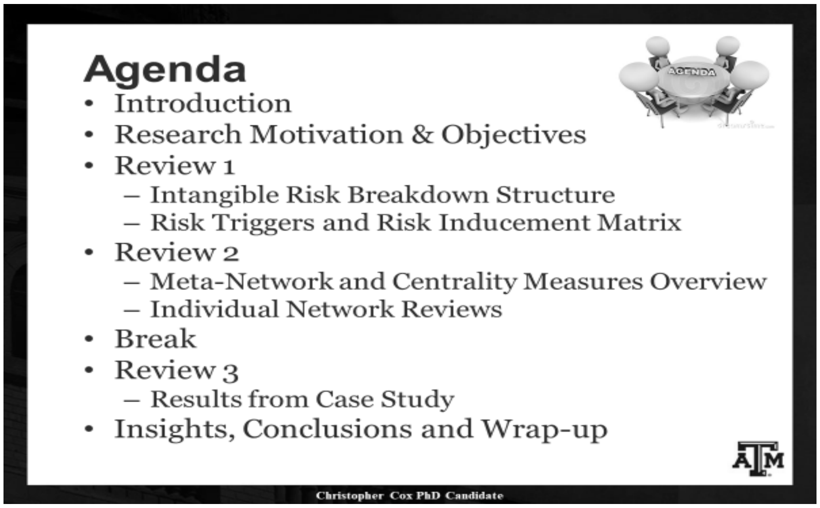


Fig. 3. SME validation workshop agenda.

At the beginning of the meeting, the researcher provided the workshop attendees with a handout consisting of assessment and comment sheets for each review session, as well as larger copies of the IRAMP templates. The first section of the workshop was a brief overview of the motivation behind the research, along with its objectives. Next was a review of the IRBS, causal factors, and RIM used in the case study. At the end of the presentation, time was allocated for clarification and discussion. Upon completion of the discussion, the attendees filled in the assessment and comment sheets for the session. This format was used for all three review sessions. In the final section of the workshop, the researcher discussed the insights gained from the research and the conclusions drawn. In the wrap-up, there was consensus support for the research hypotheses:

- *Hypothesis 1*: The development of a framework for use in identifying and prioritizing behavior-centric intangible risks will enhance the overall quality of risk management for projects and project portfolios.

- *Hypothesis 2*: A quantitative approach to characterize behavior-centric intangible risks, along with appropriate analytic measures, increases the likelihood of projects meeting their objectives.
- *Hypothesis 3*: A framework and quantitative approach developed for projects and project portfolios can be applied to each stage of the project development cycle and can enhance overall risk management effectiveness.

Chapter VI provides the detailed results from this workshop.

Limitations of Data Collection Methods

Limitations exist with any data analysis, and this research is no different. First, the data collected from the ex-post projects required the participants to refer back to causal factors and behaviors that occurred months or even a year before, possibly resulting in inaccurate information due to bias or memory lapse. Further risk of inaccurate or missing information existed in the possibility of "group-think." Second, the information regarding the behavior-centric intangible risks, their causal factors, and the agent interactions by stage was collected from three different projects with different teams. This approach could not accurately reflect how these risk and causal factors emerged from project stage to project stage. Third, the portfolio meta-analysis was limited to the three projects used in the project stage analysis and does not represent the overall portfolio balance. Fourth, the majority of the information for this research was gathered using interviews, focus groups, and a survey, making the results susceptible to response bias and reflexivity (e.g., interviewer line of inquiry influenced by the interviewee and/or the interviewee saying what they think the interviewer wants to hear). However, given the allowed time frame and the amount of time had by the project teams to provide input in light of their active workloads, a more detailed assessment was not possible.

CHAPTER III

LITERATURE REVIEW

Projects are complex sociotechnical systems operating within an organizational context. Consequently, project team effectiveness can be impacted by stakeholder behavior, company politics, inadequacy of existing processes, etc. Addressing the questions “Why do projects continue to underperform?” and “Can a behavior-centric intangible risk identification and assessment framework address this gap?” requires a transdisciplinary review of the literature. The various streams of research include project and portfolio risk, agent behavior and teamwork, intangible factors, systems science, network science, MNA, and the behavioral perspectives of operations safety and hazard analysis. Current literature was reviewed to identify relevant knowledge in these various research areas pertinent to this research. This chapter presents the results of this review and is divided into four sections. The first section provides a general description of projects and portfolios and the role they play in business delivery. The second section provides a general overview of risk management and discusses current project and portfolio risk management frameworks and risk management tools (e.g., RBS, etc.). The third section covers intangible risks and the existing methods to assess and quantify them. The fourth section explores systems, networks, and MNA, as well as their application in projects.

Projects and Portfolios

Governments and private-sector companies are faced with the need to deliver an increasing number of projects to accomplish their strategic objectives. Because of this, project management has become a core competency and has prompted change in several areas beyond developing and delivering projects. Project management principles are being used in new-product development, reengineering of internal business processes, etc. (Olsson 2008;

Pellegrinelli 1997). This has led to the emergence of the term “projectification” (Aubry and Lenfle 2012; National Research Council 2003; Sanchez et al. 2009; William and Rūta 2017). PMI has provided the following definitions for a project and a portfolio of projects:

- “A project is a temporary endeavor undertaken to create a unique product, service, or result. The temporary nature of projects indicates that a project has a definite beginning and end” (PMI 2017).
- “A portfolio is a component collection of programs, projects, or operations managed as a group to achieve strategic objectives” (PMI 2013).

The goal of project management is to deliver a project that meets an agreed-on schedule, budget, and level of quality. One of the underpinning frameworks in project management is the stage gate process (Figure 4), which is a decision-driven methodology for managing a capital project throughout its life cycle. Each stage represents an increase in the technical details of the project. The gates are formal decision points to allow management to review the project and decide if it should proceed to the next development phase, re-cycle the work, or be cancelled.

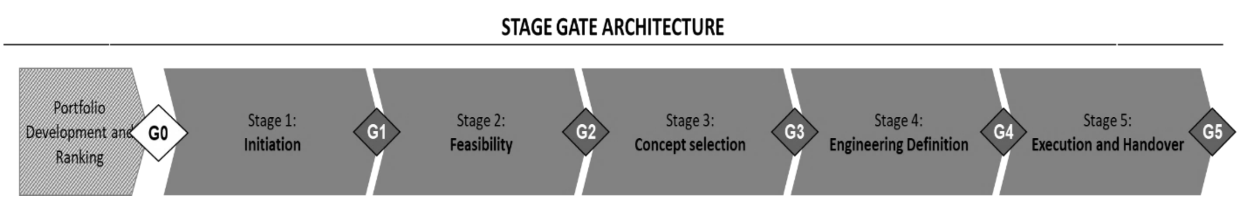


Fig. 4. Typical stage gate process indicating stage activity and formal gates.

There is no set rule as to the number of stages; however, a standard process usually has no more than six (Kerzner 2009). The objective for each of the stages is outlined as follows:

1. *Project initiation* to determine if the proposed project has sufficient economic, operational, technical, and strategic benefits to justify undertaking a more detailed feasibility study.
2. *Feasibility study* to assess a project's feasibility, develop and evaluate as wide a number of realistic concept options as possible, and then select the best concept.
3. *Concept selection* to further develop the selected concept and make it ready to start engineering definition.
4. *Engineering definition* to fully define the selected concept so that it is absolutely clear what the project is and how it will be executed, as well as the detailed cost and schedule.
5. *Implementation, handover, and completion* to execute the project as defined, with tight project controls in order to achieve the final investment decision commitments made in Stage 4.

Each project stage requires the completion of various deliverables that collectively reflect project maturity from initiation to completion. At the gate, the relevant authority decides if the project is approved to proceed to the next stage, ensuring that the project is still aligned with business objectives. If so, then it proceeds to the next phase; if not, it is either re-cycled for further definition or terminated.

Often, companies manage multiple projects of various sizes and complexities at one time. Synergistic benefits can exist if they are combined and managed as a portfolio (Jonas 2010), and the expected value to the firm can be maximized while maintaining an appropriate level of risk (Markowitz 1959). Other benefits of portfolio management are as follows (Teller and Kock 2013; William and Rūta 2017):

- Aligns the project portfolio with the strategic goals and objectives of the firm

- Forms a basis for holistic decision making regarding trade-offs
- Effectively identifies, assesses, and mitigates risk
- Monitors and reports progress in terms of goals and objectives
- Realizes the business objectives

Although a portfolio is a collection of projects, the approach to risk management in a portfolio requires a more holistic approach than an individual project (Olsson 2008; Teller and Kock 2013).

Project and Portfolio Risk

Overview

Risk has been a topic of research since the end of World War II, with the first academic books on the topic published in the 1960s (Dionne 2013). In response to the need for ensuring that projects were meeting schedule requirements, two methods emerged somewhat simultaneously in the late 1950s: program evaluation and review technique (PERT) and critical path method (CPM). PERT and CPM have similar formats: PERT charts were created for the United States Navy Polaris missile, while the CPM was developed by DuPont to analyze the implications of trading cost for accelerating a schedule (Archibald 2017; Engwall 2012). Both are based on decomposition of the project into activities and utilize a linear flow-and-sequence format. PERT and CPM provide a basis for identifying the activities vital to meeting objectives, providing a basis for identification and management of risk.

Risk, in general terms, can be viewed as the implications of an activity, along with its associated uncertainties. Consequently, risk should be regarded as a persistent presence for the duration of any activity. SRA has defined risk management as “activities to handle risk such as prevention, mitigation, adaptation or sharing” that “often [include] trade-offs between costs and benefits of risk reduction and choice of a level of tolerable risk" (Aven et al. 2018). The definition implies a cyclic process (Figure 5), starting with risk identification, and is applicable to projects and portfolios (Hofman et al. 2017; Kerzner 2009).

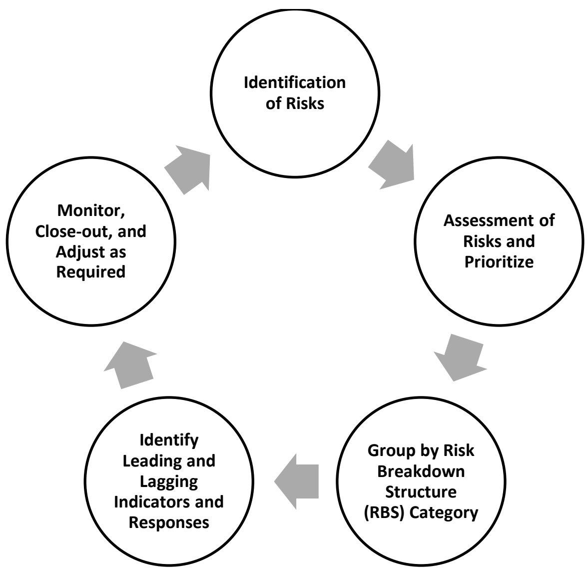


Fig. 5. Typical risk management cycle (adapted from PMI [2017]).

Project Risk

PMI has defined risk as "an uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives" (PMI 2017). PMI has separated project risk into two categories: individual project risk and overall project risk. Individual risks tend to be those managed on a day-to-day basis and may not have a direct impact on the project cost, schedule, scope, and/or quality. Some examples of individual risks would be a delay in material arrival to a job site, weld rejection rate, productivity of labor, etc. Overall project risk is the aggregate effect of uncertainty on the project as a whole and deals with the broader project environment, such as labor action, social unrest, commodity price fluctuation, etc. (PMI 2017).

Project risk has been studied through many lenses, such as Bayesian methods (Govan 2014), systems dynamics (Rodrigues 2001), neural networks (Skorupka 2004), fuzzy logic, and the analytic hierarchy process (Zhang and Zou 2007). However, these approaches have assumptions that are limiting. For instance, the analytic hierarchy process assumes that the risks act in isolation, and Bayesian methods do not consider closed-loop systems (Wang et al. 2018). Although project risk management has been recognized as an integral part of project management for decades and has experienced many analytical advances, a majority of projects do not meet their objectives. This performance gap has been attributed to an overemphasis on techniques rather than identification and assessment (Chapman 2001), as well as utilizing approaches that are steeped in linear sequential thinking (Schroeder and Jackson 2007).

Portfolio Risk

The objective of managing projects as a portfolio is to maximize the expected value to the firm while maintaining an appropriate level of risk (Markowitz 1959) and achievement of the organization's strategic goals (Sanchez et al. 2009). Although the literature regarding financial portfolio risk is extensive, research in the context of project portfolio risk is limited (Teller et al. 2014). While the basic definition of risk is the same for projects and portfolios, the overall portfolio risk exposure is greater than the sum of the affiliated projects' risks (i.e., component risks). These additional sources of risk come from the mix of projects comprising the portfolio and the potential interactions among them (i.e., structural risks), as well as the emergence of one or more overarching risks precipitated by the interaction among the component risks (i.e., overall risks). Consequently, the approach to risk management in a portfolio requires a more holistic or systemic approach to risk identification, assessment, and management than an individual project (Olsson 2008; Teller and Kock 2013).

Frameworks

Frameworks are useful to provide a structured approach for identifying and grouping individual risks, as well as the risks due to the interdependencies among projects in the context of portfolios. They can be used as checklists in risk workshops, individual interviews, etc.; can provide a common platform for organizations to capture lessons learned; and can serve as a format for ensuring consistency in risk reporting. General frameworks can be used in workshops as a checklist for the identification of risks specific to the projects being discussed (Hillson 2014). The frameworks used in this research are presented in more detail in Chapter V.

Some of these frameworks contain social or sociocultural categories but do not directly address the nontechnical or behavior-centric intangible risks. Project environments where intangible factors like respect, trust, and openness exist are more likely to have robust risk management (Uher and Toakley 1999); therefore; a risk framework that specifically highlights these characteristics has the potential to enhance a project's ability to meet its objectives.

Risk Breakdown Structure

An RBS is defined as "a source-oriented grouping of risks that organizes and defines the total risk exposure of the project or business. Each descending level represents an increasingly definition of sources of risk" (Hillson 2003). The RBS is considered an extension of systems theory in that it provides a forum for multiple disciplines (e.g., engineering, procurement, safety, etc.) to identify the implications of events from various perspectives. This can be highly effective in the identification of project or portfolio risks, as unidentified risks are unmanaged threats (Chapman 2001). The RBS is a hierarchical tree structure similar in format and utility to the

WBS. The WBS significantly influences the project management process by decomposing all project work packages into manageable levels of detail. Like the WBS, the RBS (discussed in more detail in Chapter V) provides a structure on which the entire risk management process can be developed. In addition to providing structure, the RBS framework can enhance communication and transparency by organizing risk information in a standard format for oversight, reporting, and collecting lessons learned (Hillson 2003). While this framework is useful, there is an underlying assumption of the risks being independent of the risk factors and remaining that way throughout time (Chapman 2001).

Project success is defined in terms of cost, schedule, and quality (termed the “iron triangle”), along with compliance with policies, procedures, and regulations. However, defining project success in terms of intangible factors is much more difficult. Consequently, the measurements for success and assurance are inclined to focus on the tangible aspects of the project (Atkinson et al. 2006; Teller et al. 2014), which can be seen in the tangible risk orientation of the RBS literature. Also, while portfolio risk is recognized as being greater than the sum of the individual risks given the emergence of risk from interactions of projects, the RBS is based on the whole being equal to the sum of the independent parts. Atkinson et al. asked the question, “Could it be the reason some project management is labelled as having failed results from the criteria used as a measure of success?” Perhaps current risk approaches may be experiencing a “Type II” error (Atkinson et al. 2006).

Intangible Risk Assessment in Projects and Portfolios

Intangible Risks in General

In this research project, intangible risk is defined as a nonphysical event or condition, precipitated by antecedent conditions that are unique to the firm’s administrative and organizational constructs, stakeholder composition, or culture, that can have a positive or negative effect on project objectives should it occur. Projects are developed and delivered in the context of company culture by teams of stakeholders where barriers, biases, and internal controls can adversely impact trust; if this occurs, then it is possible for dysfunctional behaviors to arise (Atkinson et al. 2006; Lencioni 2007). Portfolio risk management has a distributed dimension, creating multiple interfaces that change as the various projects move along the development timeline (Levin and Wyzalek 2015). However, the existing literature primarily focuses on tangible processes, tasks, and tools, while the qualitative behavioral implications tend to be generalized (e.g., conflict) if discussed at all. Unlike their tangible counterparts, the less tangible areas such as cooperation and dealing with interpersonal tensions tend not to have response plans to address them (Beringer et al. 2013; Jonas et al. 2013). Teller and Kock asserted the need for formalization (standard approaches for tools, policies, procedures, processes, etc.) as a means to enhance quality (e.g., avoidance of conflict by efficient resource allocation) and cooperation. They went on to mention the potential implications of bureaucracy, but did not expand on what these might entail or impact (Teller and Kock 2013). This underscores the need for project and project portfolio risk management to adopt a broader perspective and a more holistic approach that goes beyond the management of tangible project risks (Hofman et al. 2017; Olsson 2008; Pellegrinelli 1997). While project and project portfolio risk identification, assessment, and management are considered important dimensions of the management process (De Reyck et al. 2005; Teller and Kock 2013; William and Rūta 2017), they do not directly address the intangible risks associated with stakeholder behaviors, motivations, and culture.

The empirical evidence for intangible risks in general is sparse, and what exists tends to be conceptual, with minimal focus on behaviors and the causal factors that influence them. Even when behavior-centric intangible risk (e.g., conflict) is presented, frameworks to systematically identify and provide a level of measure are not attendant. The actions of project teams blocking each other and displaying opportunistic behavior with regard to resources is mentioned, but empirical evidence is lacking (Jonas et al. 2013). Others have identified the clarity of roles, strong stakeholder involvement, coordination between projects, conflicting project objectives, lack of cross-functional teamwork, and interpersonal conflicts as having effects at the portfolio level (Beringer et al. 2013; De Reyck et al. 2005; Hofman et al. 2017). Although behavioral conditions have been identified generally (interpersonal conflict) and causal events specifically (conflicting project objectives), there is no information regarding how they might emerge and interact or how to analyze them.

Intangible Risks: Behaviors

The ability to classify and quantify uncertainty is an important dimension of risk assessment. Unlike the valuing of intangible assets such as intellectual capital (O'Donnell et al. 2003), behavior-centric intangible risks by their nature cannot be easily quantified and require a departure from the existing assessment methods (Barber 2005). In their paper “A Multiple-Objective Decision Model for the Evaluation of Advanced Manufacturing Systems Technologies,” Johann Demmel and Ronald Askin asserted that the traditional approach to investment decision making using quantitative financial metrics is an “oversimplification.” They went on to propose a multiobjective decision model that factors intangible benefits into the decision-making process. This approach allowed them to account for manufacturing intangibles such as “greater flexibility, shorter lead time, and increased knowledge in the use of new technologies” (Demmel and Askin 1992). The inclusion of intangibles in the decision-making process can be extended to intangible risk factors in projects and portfolios. However, methods for assessing the implications of issues like outsourcing on project stakeholder performance or the future impacts of misaligned priorities are exiguous in the current literature (Nogeste and Walker 2005). Therefore, an opportunity exists to extend the RBS to the behavior-centric intangible factors that impact stakeholder performance throughout the project life cycle.

Behavior-centric intangible factors are a surreptitious weakness for people and teams. Anthropological and sociological studies have shown that social networks impact the attitudes of individuals, as well as the way they perceive the rules of acceptable interaction (Bienenstock et al. 1990). Because of this, the ways that people interpret and respond to situations are highly personal and deeply rooted in strong emotions, past experiences, and personal values. Complexity increases as individuals are assembled in teams, with each individual interpreting interactions with others differently (Dargin 2013). Agent-based modeling is an emerging area of study for addressing cognitive patterns; however, Macal and North highlighted the limitations of agent-based modeling. They pointed out that "the fundamental assumption . . . that people and their social interactions can be credibly modeled at some reasonable level of abstraction for at least specific and well-defined purposes, if not in general" (Macal and North 2005), is tenuous at best. Professional sports is an area where intangibles are widely discussed. It is possible for coaches and staff to judge a player by the numbers; however, the ability to measure attributes like passion, heart, personality, team chemistry, etc. remains elusive. Aaron Shatz, founder of Football Outsiders, summed this up quite well: "The intangibles are important, and we just don't have numbers for that" (Sauser 2009). Consequently, there is no generalized formula or spreadsheet to quantify the implication of how individuals within teams react to change, their ability to effectively adapt their behaviors or actions, or how under- or overconfident they are (Dargin 2013).

The importance of teamwork can be seen across society, from athletics to academics to government to business. There is a seemingly endless supply of literature regarding teamwork; the PMI library alone has more than 1,000 publications on the topic. While the requirements and definitions regarding teamwork differ, there is agreement that teamwork is the ultimate source of competitive advantage (Lencioni 2007; Salas et al. 2015). While a detailed assessment of teamwork was outside the scope of this research, a general review of the literature was completed. In the context of this research, teamwork is defined as "a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively toward a common and valued goal / objective / mission" (Salas et al. 2015). In their review of the literature, Rousseau et al. identified 29 different frameworks identifying the dimensions of team behaviors (Rousseau et al. 2006). Salas et al. proposed a framework composed of "core processes (composition, culture, and context) and emergent states (cooperation, conflict, coordination, communication, coaching, and cognition)." They provided definitions and expected results from the existence of these processes and states, but provided no means to objectively determine their presence in a team (Salas et al. 2015). Lencioni explored effectiveness of teams from the perspective of the presence or absence of dysfunctional behavior in the following five dimensions: "trust, conflict, commitment, accountability, and results" (Lencioni 2007). Unlike other frameworks, Lencioni's work provided a rubric to assess team behaviors.

Human emotions and cognition are themselves dynamic nonlinear systems (Afraimovich et al. 2011). Because projects are developed and delivered by teams of people, it stands to reason that risks have an emotional and cognitive dimension. This accentuates the importance of understanding behavior-centric intangible factors, which by their nature influence the project in ways that are difficult to quantify. Behavior-centric intangible risks can manifest themselves in human interactions and can impact an individual's ability to adapt, utilize experience, communicate, cooperate, adapt to culture, work effectively as a team, and engage in interpersonal relationships, leadership, innovation, and conflict resolution (Bankolli and Jain 2014; Nogeste and Derek 2008; Thamhaim and Wilemon 1975). However, many important project causal factors can be associated with internal procedures (Barber 2005) and the project management process itself (Ward and Chapman 1995). These nonlinear manifestations can cause fundamental changes in the network dynamics, such as spreading or cascading of a particular risk or risks leading to unexpected outcomes (Yuan et al. 2018). Therefore, behavior-centric intangible risks can be viewed as an open-system phenomenon (Clark-Ginsberg et al. 2018).

Current methods for the identification and prioritization of risks are linear in nature and cannot accommodate the dynamic aspects of human behavior and their causal factors (Clark-Ginsberg et al. 2018; Wang et al. 2018). Risk classification is process-focused (Tah and Carr 2001), and the categorization of behavior-centric intangible risks, if addressed at all, is done at a high level (OGA 2017). Empirical studies (primarily interview or survey) have focused on a specific behavior-centric intangible factor such as complexity of resource allocation (Sanchez et al. 2009), management interaction (Beringer et al. 2013), or managing conflict (Brockman 2014; Gardiner and Simmons 1992; Thamhaim and Wilemon 1975). Thamhaim and Wilemon found that behavior-centric intangible risks can vary throughout the project cycle. During the initial stages where project requirements are being developed, input from key stakeholders is crucial; during the execution stage, appropriate resource assignment is critical for project success (Thamhaim and Wilemon 1975; Ward and Chapman 1995). However, there is no integrated empirical approach for the development, classification, categorization, and prioritization of intangible risks in projects or project portfolios.

The existing literature regarding behavior-centric intangible risk in projects is sparse and almost nonexistent when looking at project portfolios. What does exist in the current literature tends to focus on the implications of individual behavior-centric intangible risk factors, many times characterized generally as conflict or interpersonal behavior, on project and portfolio performance (Hofman et al. 2017; Olsson 2008; Sanchez et al. 2009; Teller et al. 2014). There are many stakeholder perceptions and responses having differing relationships with each other that can lead to the occurrence of intangible risks (Yuan et al. 2018). Effective identification and management of these potential intangible risks require the ability to identify their multifaceted interaction. There is no available research taking a holistic approach to assessing intangible risks or comprehensive methodologies to specifically address the evolution of intangible risks from a portfolio perspective during each stage of the project development cycle (Hofman et al. 2017).

Systems, Networks, and Metanetwork Analysis

Systems Theory

General systems theory (GST) has its origin in the quest to discover the laws of biological systems. In the late 1920s, Ludwig von Bertalanffy recognized the need and wrote, “Since the fundamental character of the living thing is its organization, the customary investigation of the single parts and processes cannot provide a complete explanation of the vital phenomena. This investigation gives us no information about the coordination of parts and processes.” This led to the system theory of the organism and became the basis for GST (Klir 1972). GST provides a framework to understand the nature of systems based on the premise that the interaction of independent elements leads to increasing interdependence and a reduction of each element’s autonomy.

Modern systems theory, or systems science, manifests itself in many subfields of study; however, in general it provides an interdisciplinary framework to investigate the attributes of complex environmental, social, and technical systems that collectively interact to produce a result (Skyttner 2006). The *IEE Standard Glossary of Software Engineering Terminology* defined a system as "a collection of components organized to accomplish a specific function or set of functions" (IEEE 1990). Systems can be described as simple, complicated, or complex. Simple systems are those with a singular solution achieved by a single path. Outcomes are predictable, and the relationship between cause and effect is known. Complicated systems are those where there can be multiple paths to a single solution, but cause and effect are separated by time and space. Complex systems have multiple paths and solutions, along with emergent properties (Schloss 2014). Emergent properties are the byproduct of the interactions and interdependencies of system elements and are both unforeseeable and unattributable (Zhu and Mostafavi 2017). In the domain of complex systems, traditional planning and assessment tools are not effective (Schloss 2014). To illustrate this, a small ecosystem can be been compared to what the National Aeronautics and Space Administration (NASA) has described as the most complex machine ever built—the space shuttle—which "has more than 2.5 million parts, including almost 370 kilometers (230 miles) of wire, more than 1,060 plumbing valves and connections, over 1,440 circuit breakers, and more than 27,000 insulating tiles and thermal blankets" (NASA 2010). Here, the whole is the sum of its parts, the whole is static, and the outputs can be predictable. The ecosystem of a small pond, on the other hand, experiences a different dynamism. A change in the food chain, the climate, or human intrusion can have adaptive and emergent effects that cannot be predicted, making the whole greater than the sum of its parts. While both of these examples are a collection of components that can accomplish their functions, the space shuttle is a complicated system, while the small pond is a complex system of systems given the propensity for emergent behavior.

Systems of Systems

Industries from healthcare to aerospace widely refer to systems of systems; however, a proper demarcation between a conventional monolithic system and a system of systems is elusive (DeLaurentis 2005; Maier 1998). Monolithic systems are based on the reductionist view with the following assumptions: (a) independent components that cannot operate on their own, (b) no distortion in the results due to analyzing each component separately, (c) component performance individually or collectively being the same, (d) no nonlinear interactions or feedback loops, and behaviors being treated as distinct events over time (Leveson 2017). A simple example of a monolithic system is a traditional watch.

A system of systems, on the other hand, is a collection of systems that can perform a standalone function, as well as interact as an entity. In light of this, Maier proposed five characteristics to differentiate a system of systems from a monolithic system: operational independence, managerial independence, emergent behaviors, evolutionary development, and geographic distribution (Maier 1998).

- *Operational independence* of the components is defined as the component systems being able to operate independently (Maier 1998). In the context of project risk management, these components can be defined as stakeholder groups that must operate independently of each other (e.g., engineering, operations, etc.) and policies and procedures that are a standalone ubiquitous presence. Various stakeholders working together within the boundaries of policies and procedures enhances the probability that a project will meet its objectives.

- *Managerial independence* of the components indicates that the component systems operate independently regardless of being integrated in the system of systems (Maier 1998). In the project context, this can be seen in a distributed management structure. Project managers or portfolio managers must rely on the managers of support groups to make decisions within their disciplines (Ford and Randolph 1992; Rousseau et al. 2006). All of these components are managed independently, but must deliver in concert to achieve project objectives.
- *Emergent behaviors* are defined as events that cannot be predicted from existing knowledge of the system's subsystems (DeLaurentis 2005). Emergence is the phenomenon that makes a system of systems greater than the sum of its constituent parts (Sage and Cuppan 2001). In projects, behaviors emerge because of intangible factors including culture of the organization, beliefs of the agents, interactions among agents, and the firm's political landscape (Ancona et al. 1999; Rousseau et al. 2006). These causal factors cause human agents to adapt to changes in the environment and can precipitate behavioral responses (Cook and Rasmussen 2005). The behavior-centric responses can impact the project outcomes.
- *Evolutionary development* has been defined by DeLaurentis and Ayyalasomayajula as the "system of systems [being] never completely, finally formed; it constantly changes and has a 'porous' problem boundary" (DeLaurentis and Ayyalasomayajula 2009). Sage and Cuppan pointed out that the "development of these systems is evolutionary over time and with structure, function and purpose added, removed, and modified as experience with the system grows and evolves over time" (Sage and Cuppan 2001). PMI has described the evolution of a project as progressive elaboration, which involves continuously

improving and detailing a plan as more specific information and accurate estimates become available. Progressive elaboration allows a project management team to define work and manage it to a greater level of detail as the project evolves (PMI 2017). The project stage gate process detailed earlier is a visual representation of this evolution.

- *Geographic distribution* has been defined by DeLaurentis and Ayyalasomayajula as "constituent systems [that] are not physically co-located, but [that] can communicate" (DeLaurentis and Ayyalasomayajula 2009). In large energy projects, it is not uncommon for the engineering to take place in one location, the fabrication of the facilities to be in at least one other location, and the installation in another. While communication efficiency can vary, there are a number of technologies available for project teams and contractors to effectively interact.

In addition to its characteristics, every system of systems can be considered unique (DeLaurentis 2005) with regard to the way it is managed. Maier presented three approaches to managing a system of systems, directed, collaborative, and virtual:

- "Directed systems-of-systems are those in which the integrated system-of-systems is built and managed to fulfill specific purposes. It is centrally managed during long-term operation to continue to fulfill those purposes and any new ones the system owners may wish to address. The component systems maintain an ability to operate independently, but their normal operational mode is subordinated to the central managed purpose" (Maier 1998).
- "Collaborative systems-of-systems are distinct from directed systems in that the central management organization does not have coercive power to run the system. The

component systems must, more or less, voluntarily collaborate to fulfill the agreed upon central purposes” (Maier 1998).

- “Virtual systems-of-systems lack both a central management authority and centrally agreed upon purposes. Large-scale behavior emerges, and may be desirable, but the supersystem must rely upon relatively invisible mechanisms to maintain it. A virtual system may be deliberate or accidental” (Maier 1998).

A system of systems will exhibit all of the aforementioned characteristics and levels of management control to some extent. Based on previous work (Maier 2008; Schloss 2014), a project can be classified as a complex system of systems. However, projects have a social network dimension in that they are defined, developed, and delivered by a potentially diverse group of human agents. The focus of systems science is on the technical dimension of projects, but the interaction of human agents must be accounted for; this is the focus of network science.

Network Science

Systems involving human agents can be expressed as social networks. Network theory provides insight into social interactions such as the communication of information or knowledge and the implications of social groups on individual behavior. Network science is one of the few research fields that is able to trace its genesis to a specific historical event. Graph theory, the mathematical foundation of network science, was introduced by Leonard Euler in 1736 as a means to address a contemporary mathematical enigma: Was it possible to walk across the seven bridges of the city of Konigsberg, Prussia without crossing any bridge more than once? Using a graph composed of edges (links) and vertices (nodes), Euler proved it impossible. His negative solution was published in a document entitled “Seven Bridges of Konigsberg.” However, while his objective was to address the puzzle, his work accentuated the principle that networks have predisposed properties inherent in their structures that affect their behaviors (Barabási 2016). The use of graph techniques provides a basis for the visualization and statistical assessment of networks (Merrill et al. 2007).

Modern network analysis emerged as a field of academic inquiry in the 1970s. The initial focus was to understand the inherent complexities of social networks (personal and professional) to assess how information is transmitted. This was accomplished by representing the system elements (people and whom they interact with) as nodes (people) and edges (lines showing the connections). The discipline further expanded into areas such as cascading failures in power grids, biological and ecological systems, and trade networks (Barabási 2016). Construction projects in the oil and gas sector can be viewed as complex networks with many interconnections and interactions among people, resources, and activities (Zhu and Mostafavi 2017). A portfolio containing many projects in multiple locations at various stages of development with multiple heterogeneous stakeholders and interaction among the individual projects creates another level of complexity beyond the capability of traditional network analysis techniques (Carley et al. 2007). Carley pointed out that combining the social network and project management perspectives is necessary to analytically assess the dynamic complexity resulting from the interactions of a heterogeneous network of networks (Carley 2002).

Sociotechnical Networks

Major accident assessment is another area of study where the complexity of sociotechnical systems exists. O’Hare proposed the “wheel of misfortune” to conceptualize the interactions among human agents, tasks, policies, local actions, procedures, and philosophies specific to aviation accident investigation (O'Hare 2000). In the arena of industrial plant operation safety, Rasmussen conceptualized the interaction between man and machine as a dynamic model of safety and system performance. His framework (discussed in further detail in Chapter IV) is a troika of constraints (economic, workload, and performance), with operating points being influenced by subjective preferences exhibiting Brownian movements within a space of possibilities. As the operating point enters the error margin, the activities associated with the safety culture act as a countervailing force. However, should the operating point breech the boundary of functionally acceptable performance, a major accident is instigated (Rasmussen 1997).

Both Rasmussen and O'Hare asserted that existing tools used for risk and accident investigation are not sufficient for use in sociotechnical systems given their complex nonlinear (or causal web) nature. While neither of their conceptual models directly addresses human behavior, they recognized it as being "idiosyncratic and unpredictable," where a seemingly innocuous decision to deviate from a standard activity can lead to a catastrophic event (O'Hare 2000; Rasmussen 1997). Projects face a dynamic similar to Rasmussen's safety and system model, where multiple networks (gradient toward efficiency, gradient toward least effort, countergradient for safety culture) exist within the overall delivery network. Both O'Hare's and Rasmussen's models of complex dynamic networks are conceptual and do not provide a means to quantify the forces working within the boundaries. Carley, on the other hand, proposed an analytic approach to assessing multiple interacting networks using the metanetwork construct and dynamic network analysis techniques (Carley 2002).

Metanetwork Analysis

The metanetwork (i.e., a network of networks) is a framework that is useful in representing the interactions among various networks. The fundamental building blocks of networks are nodes that can represent tasks, agents, information, resources, etc. in organizations, and their interactions are referred to as links. Carley proposed an ontological model consisting of 10 interlinked networks to assess how changes in one network impact others in this network of networks (Carley 2002). Once these networks are combined, the inherent metanetwork complexity can be quantitatively assessed in terms of the individual elements and their interactions. Taking this approach makes available a plethora of existing SNA measures. Table 3 is the metamatrix construct put forth by Carley et al. Carley et al. went on to assert that the "ontology" of the metamatrix can be used to analyze multiple sociotechnical networks and to assess topics such as "power, vulnerability, and organizational change in diverse contexts" (Carley et al. 2007).

Table 3. Generic metamatrix (National Research Council 2003)

	People	Knowledge/resources	Events/tasks	Organizations
People	Social network	Knowledge network	Attendance network	Membership network
Knowledge/resources		Information network	Needs network	Organizational capability
Events/tasks			Temporal ordering	Institutional support/attack
Organizations				Interorganizational network

Li et al. recognized the implications of the project delivery environment and the complexity of human interactions to not be adequately addressed in traditional approaches to the allocation of tasks in projects. They extended the metanetwork to construction projects using a six-network construct of agents, knowledge, and tasks (Li et al. 2015). Wang et al. highlighted the role of tangible risk factors (e.g., construction quality, not following procedures, etc.) in industrialized building construction projects (Wang et al. 2018). Others have utilized a 10-network metanetwork (agent, information, resource, task) to assess construction project performance under uncertainty (Zhu and Mostafavi 2017). However, a metanetwork construct including behavior-centric intangible risks, their potential causal factors, and a method to analyze and measure organizational response opportunities is absent in the current literature.

Summary

Effective risk identification and assessment is considered a strategic enabler to manage the discrete risks of projects, as well as the interactions/interdependencies of projects within a portfolio. As projects move through the development cycle, the risk profiles at each of the stages can change, and these changes can have emergent effects at the portfolio level. In addition to the complexity and turbulence of the business environment, project delivery is faced with internal uncertainties that are both quantitative (e.g., resource allocation, financial resources, portfolio structure) and qualitative (e.g., behavior, effectiveness of communication and information). The current methods being utilized are steeped in linear sequential thinking (Schroeder and Jackson 2007). The RBS, while useful, utilizes a decomposition approach, and risks are independent of the risk factors and remain that way throughout time (Chapman 2001). Therefore, the existing risk management methods are appropriate for simple or complicated systems, but not for those considered complex (Schloss 2014).

Sanchez et al. pointed out the behavioral interactions among individuals as a source of portfolio uncertainty; however, the frameworks developed are generic, and the methodologies do not consider the dynamic interactions between the individuals and the other parts of the portfolio development network. They proposed, “A social network standpoint would help to regard projects, programs or portfolios as a system of interdependent elements, activities, or resources with a variety of relationships changing constantly over time" (Sanchez et al. 2009). Chinowsky et al. proposed an SNA approach for enhancing project team performance. They defined two components that lead to high-performing teams: dynamics (comprising trust, values, reliance, and experience) and mechanics (comprising knowledge exchange, information exchange, and communication) (Chinowsky et al. 2008). However, a holistic approach to the identification, assessment, and quantification of the behavior-centric risks to effective team behavior is not evident in the literature.

Rasmussen's dynamic model of safety and system performance is a functional abstraction of commercial plant operations activities being bounded by economic, workload, and performance requirements that influence the behavior (i.e., causal factors) of the people within the system. Projects and portfolios have similar boundary conditions and behavioral responses. Consequently, plant operations safety and project execution can be conceptualized as a number of interacting systems with a human behavior dimension. MNA can be used to model either of these as a system of networks composed of multiple nodes and links. The nodes can be people (i.e., agents); knowledge, equipment, objectives, or actions (i.e., behaviors); tasks or events (i.e., risk factors); or organizations. MNA provides a means to express complex relationships and has been utilized for project management in the areas of resilience (Zhu and Mostafavi 2017), tangible risk factors (e.g., construction quality, not following procedures, etc.) in industrialized building construction projects (Wang et al. 2018), and task assignment (Li et al. 2015). Therefore, the use of MNA creates the opportunity to utilize existing SNA measures to objectively assess causal factors and their behavior-centric responses.

Conclusions, Point of Departure, and Knowledge Gaps

Conclusions

The review of the current literature identified several opportunities to enhance the existing body of knowledge. These prospective areas include (a) development of a behavior-centric framework for the identification of behavior-centric risks and causal factors to be used in project and project portfolio risk identification by extending the current RBS methods, (b) development of an effective means to align behavior-centric intangible risks with the requisite causal factors, and (c) use of MNA to assess the systematic implications of behavior-centric intangible risk factors and identify analytical measures and organizational response opportunities. This assessment of the current literature validates the objectives of this research put forth in Chapter I.

This research builds on Rasmussen’s conceptual framework by utilizing the IRAMP methodology to quantitatively assess the systemic implications of idiosyncratic and unpredictable behaviors. This approach may be thought of in terms of Bernard of Chartres’s metaphor “standing on the shoulders of giants,” as this research draws on the important work of others (Bordage 2009).

Point of Departure

Projects and project portfolios are complex (multiple paths with multiple possible outcomes) sociotechnical systems (Carley 2002); however, the existing risk assessment methods presented in the literature are more appropriate for systems that are considered simple or complicated (single or multiple paths to the same outcome, cause and effect are known or knowable) monolithic systems (DeLaurentis 2005; Maier 1998). Rasmussen’s conceptual framework established a hybrid manifestation of Maier’s system of systems and the adaptive behaviors of human agents being emergent properties that can impact performance (Maier 2008; Rasmussen 1997). Integrated systems theory and network theory were extended into the MNA framework, creating the ability to quantify key network elements (Carley 2002), and MNA was extended to construction projects (Zhu and Mostafavi 2014). Researchers then incorporated tangible construction project risk into MNA (Li et al. 2015; Wang et al. 2018). However, a way to identify and quantitatively assess the implications associated with behavior-centric factors has not been addressed to date. Without a means to identify and prioritize these risk factors, they cannot be proactively addressed; this lack of response planning can potentially impact the achievement of project objectives. Table 4 provides a perspective of the streams of previous research incorporated by the current research to create the IRAMP framework to address the complexity of behavior-centric intangible risks.

Table 4. Research streams addressed by researchers

	Rasmussen (1997)	Carley (2002)	Zhu (2016)	Wang et al. (2018)	Li et al. (2015)	This research
Operational safety risk	√					
Project risk			√	√	√	√
Portfolio risk						√
Intangible risk						√
Systems theory	√	√	√	√	√	√
Network theory		√	√	√	√	√
Team performance factors						√
Organizational design		√				√

Knowledge Gap Closure

The research objectives and gaps in the current literature have been identified in the preceding sections of this chapter. In this section, the research questions are aligned with the research objectives addressing them, as well as what research gaps are filled.

Research Area 1

- *Research question:* Can a framework be developed for use in project risk workshops that can assist project teams to effectively identify and assess behavior-centric intangible risks and their causal factors during each stage in the project development cycle?
- *Research objective:* Formulate an analytical framework that can be used in project risk workshops to effectively identify and assess behavior-centric intangible risks in projects and project portfolios. This framework will be integrated into existing risk management processes for each stage in the project development cycle.
- *Gap addressed:* Tools to specifically identify behavior-centric intangible risks aligned with causal factors that can be efficiently integrated into existing project risk management frameworks.

Research Area 2

- *Research question*: Can an analytical tool kit be developed to assess sociotechnical complex networks, along with the network analysis measures of centrality, that can be used to identify organizational or procedural modifications to enhance project delivery performance?
- *Research objective*: Identify appropriate analytical tools and network measures of centrality (e.g. betweenness, cognitive demand, etc.) to quantify behavior-centric

intangible risks. These measures will be used to provide insights regarding potential organizational or procedural modifications for performance enhancement.

- *Gap addressed*: The ability to quantify behavior-centric intangible risks through the development of an analytical model capable of assessing complex systems, identification of SNA measures applicable to behavior-centric intangible risks and their causal factors, and MNA extension to include intangible risks and their causal factors.

Research Area 3

- *Research question*: Can the framework, tools, and measures be validated in an active project portfolio for an energy firm and specific recommendations be identified to mitigate specific behavior-centric intangible risks?
- *Research objective*: Empirically validate the proposed tools and measures in an active portfolio of projects for an oil and gas corporation and provide specific recommendations for mitigating identified risks
- *Gap addressed*: First-ever empirically validated behavior-centric intangible risk assessment and implementation in a corporate active project portfolio setting.

CHAPTER IV

CONCEPTUALIZATION OF A SYSTEM-OF-SYSTEMS FRAMEWORK FOR BEHAVIOR-CENTRIC INTANGIBLE RISK META-ANALYSIS

Introduction

There is an African proverb that says that the best way to eat an elephant is one bite at a time. This concept of decomposition can be traced back to the earliest of the reductionist philosophers, Thales of Miletus (ca. 600 BC). His underlying hypothesis of water being the fundamental substance from which everything else is composed laid the foundation for looking at the world from an atomistic perspective. In science and engineering, this approach is referred to as analytic reductionism and has been the conventional approach to address complex systems. This process simply decomposes the system into physical, functional, and behavioral components, analyzes each individually, and then recombines them to get an overall result; said another way, the whole is equal to the sum of its parts. While the role of behavior is recognized, it is treated as distinct events occurring over time and not as a continuous flow of influence. This approach rests on the assumption of independence of subelements. There is no distortion in the results because of analyzing each component separately; the components’ performance is the same whether operating solo or as part of the system, and there are no nonlinear interactions or feedback loops (Leveson 2017). The use of decomposition to address complexity has become somewhat of a dogma in project assessment; however, in light of the current state of project performance, a more integrative or gestalt-like approach must be considered.

Currently, decomposition of a project into its subsystems (WBS) or risks (RBS) to a detailed level is common practice. These approaches tend to be highly prescriptive and mechanistic, with disproportionate emphasis placed on the techniques of the process (Chapman

2001). These techniques are steeped in linear sequential thinking, making them unsuitable for use given the complex nature of projects (Schroeder and Jackson 2007). A project by its nature is a complex sociotechnical system of systems, where feedback loops, adaptive behaviors, and emergent properties make the whole greater than the sum of its constituent parts. Consequently, risk processes and tools must address this complexity to effectively identify and assess the project risk landscape. Examining projects as systems of systems can enhance theoretical and methodological attempts to create integrated tools and techniques to assess performance in complex projects (Zhu and Mostafavi 2014).

Conceptual Framework—System of Systems

DeLaurentis proposed a taxonomy for a system of systems as “connectivity, heterogeneity, and autonomy of the component system.” Visually, he presented this system of systems in a three-dimensional (3D) vector space with the connectivity axis ranging from “fully independent to fully interdependent,” the heterogeneity axis extending from “fully technological to fully human-based,” and the autonomy (or control) differing from “fully centralized to fully autonomous” (DeLaurentis 2008). This taxonomy can be applied to sociotechnical systems like projects or plant operations where agent activities follow similar patterns of independence to interdependence. The interface with technology can be fully automated or fully manual, and various activities or operational states can range the spectrum of centralized to autonomous. Rasmussen’s dynamic model of safety and system performance is a similar bounded system where the management’s drive for cost efficiency and the worker’s response to additional workload interact and move toward a technical limit of safe operation. It is within this 3D vector space where the nonlinear implications of human behavior emerge.

Rasmussen was interested in the question, “Do we actually have adequate models of accident causation in the present dynamic society?” His methods to assess safety were based on structural decomposition rather than functional abstraction. His approach conceptualizes the interaction between human and machine as a dynamic model of safety and system performance. His framework (Figure 6) is a troika of constraints (economic, workload, and performance), with operating points being influenced by management pressure for efficiency and working level response to workload implications. However, the working level responds to efficiency pressure by subjective preferences, creating emerging Brownian movements within a space of possibilities. As the operating point enters the error margin, the activities associated with the safety culture act as a countervailing force. Should the operating point breach the boundary of functionally acceptable performance, a major accident is instigated (Rasmussen 1997).

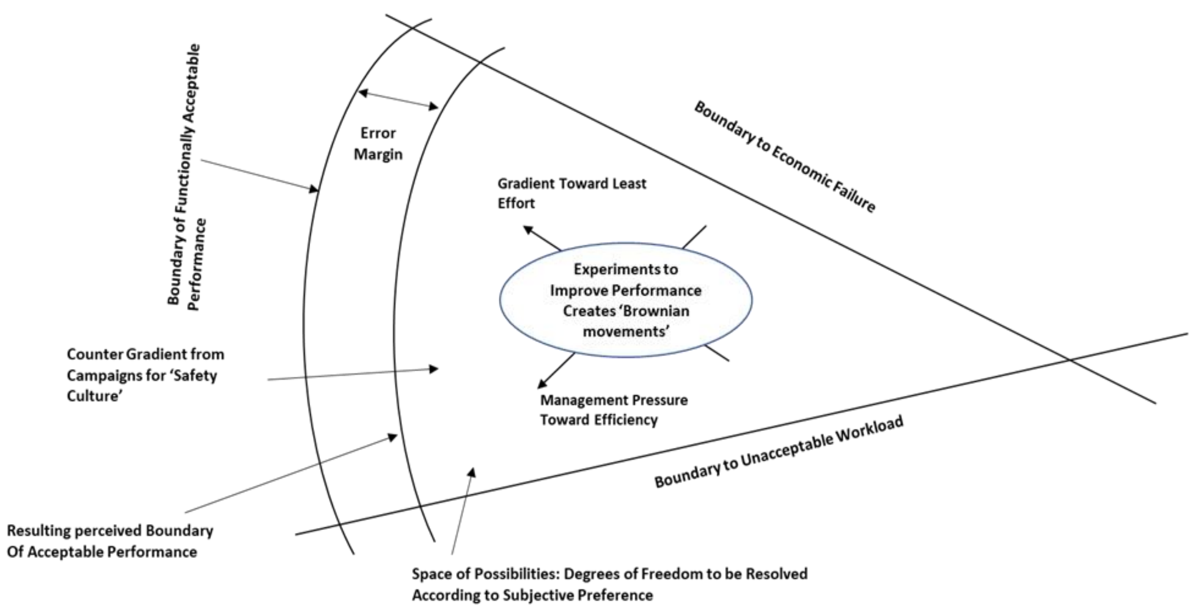


Fig. 6. Dynamic model of safety and system performance (adapted from Rasmussen [1997]).

Rasmussen’s conceptual model is consistent with Maier’s abstraction of management control. Maier’s management dimensions of directed, collaborative, and virtual governance are mirrored by Rasmussen’s conceptualization of safety performance as economic- and workload-induced Brownian movements. The subjective preferences of the operations personnel can move the operating point toward the boundary of functionally acceptable performance. If this boundary is breached, then a large-scale accident occurs. Alignment of Maier’s framework to Rasmussen’s conceptualization is shown in Figure 7.

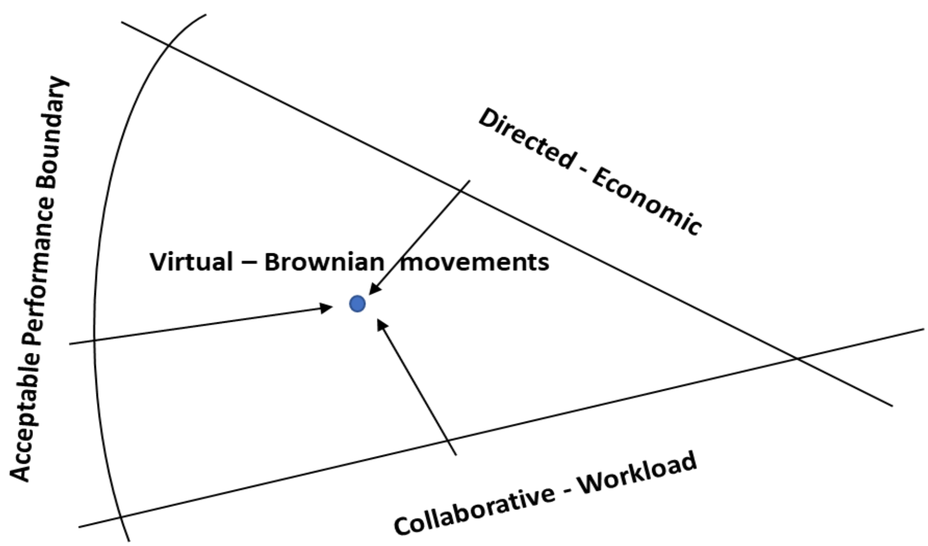


Fig. 7. Maier’s framework abstracted in Rasmussen’s format (adapted from Maier [1998] and Rasmussen [1997]).

Like plant operations, projects face financial, workload, and performance boundaries. Rasmussen’s model can be extended to projects where the boundaries are commercial performance in terms of cost, schedule, and scope; human performance in terms of workload, adequate competent resources, workflow, and procedure; and acceptable project performance—if the boundary is violated, then the project objectives are adversely impacted. Extension of Rasmussen's dynamic model of safety and system performance to project performance is shown in Figure 8. Movement in the space between the boundaries is driven by the adaptation of the human agents. Rasmussen pointed out that "idiosyncratic and unpredictable" behaviors can lead to a seemingly innocuous decision to deviate from a standard activity, which can lead to a catastrophic event (Rasmussen 1997). Interestingly, his statement conforms to the generalized risk statement structure, "Because of <one or more causes>, <risk> might occur, which would lead to <one or more effects>" (Hillson 2006).

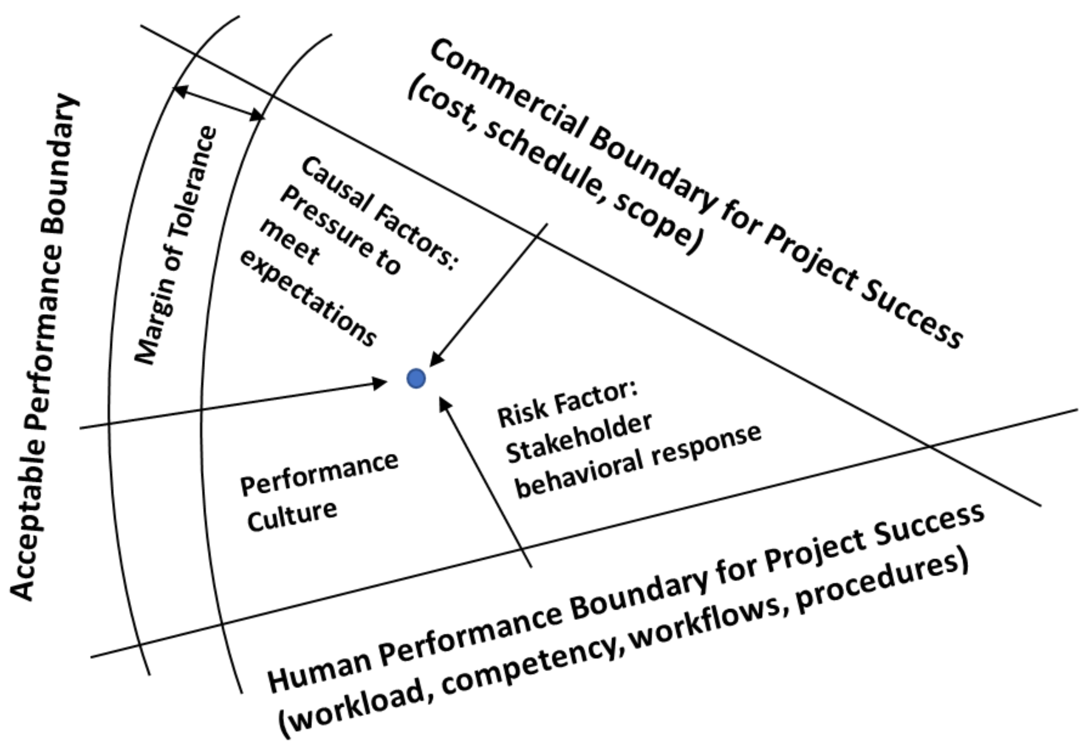


Fig. 8. Extension of dynamic model of safety and system performance to project performance (adapted from Rasmussen [1997]).

Conclusion

Rasmussen’s conceptualization recognized the need to integrate systems theory with a cognitive framework. Extending Rasmussen’s model to projects, integrating behavior-centric intangible team factors with systems theory and MNA, and utilizing existing SNA measures open a new vista on project and portfolio risk management. The dynamic model of project behavior-centric intangible risks is a network of networks, where the interactions of commercial influence and performance culture on human performance with the resulting emerging responses are themselves interrelated networks. This network of networks is the foundation of the IRAMP framework. Extending the dynamic model of project behavior-centric intangible risk is discussed further in Chapter VI and applied in a live project setting in Chapter VII.

CHAPTER V

INTANGIBLE RISK ASSESSMENT METHODOLOGY FOR PROJECTS: BEHAVIOR-CENTRIC RISK DATA COLLECTION

Context

In this chapter, the IRAMP is presented, as are the data collection and validation processes. The general frameworks used in conventional RBS are discussed as a basis for the development of the IRBS. Then, each of the components of the IRAMP—IRBS, causal factors, and RIM—is discussed in detail.

Frameworks and the Risk Breakdown Structure

Projects and portfolios of projects are conceptualized as complex sociotechnical systems where adaptive human behaviors emerge in response to the dynamic nature of the project environment. This emergence and adaptability transcend existing risk techniques that are based on the assumption that cause and effect are known ex-ante. Kyriakidis et al. explored the possibility of a generic framework for understanding the implications of human work performance in cross-functional sociotechnical environments. Their research of performance shaping factors (PSFs) in operational safety found that a “prerequisite for learning from such taxonomies is to construct them in ways that capture the generic aspects of man-machine interaction along with the characteristics of the specific technological domains” (Kyriakidis et al. 2018). Behaviors shaping performance in projects and project portfolios have both a generic dimension and specific dimension. Trust among stakeholders is a generic requirement for a project to be successful (Atkinson et al. 2006); how trust is established or breached is specific to the particular project environment. IRAMP provides a process to proactively identify factors that lead to behavior-centric intangible risks emerging in specific project contexts.

Frameworks are used as a structured approach for identifying and grouping individual project risks and the interdependent risks between projects in the context of portfolios. They can be used as checklists in project risk workshops, individual interviews, etc., can provide a common platform for organizations to capture lessons learned, and can serve as a format for ensuring consistency in risk reporting. The general frameworks shown in Table 5 were used in workshops as checklists for the identification of risks specific to the projects being discussed (Hillson 2014).

Table 5. General project risk frameworks

Acronym	Definition
PESTLE	Political, economic, social, technological, legal, environmental
STEEPLE	Social, technology, environmental, economic, political, legal, ethics
InSPECT	Innovation, social, political, economic, communications, technology
SPECTRUM	Sociocultural, political, economic. competitive, technology, regulatory/legal, uncertainty/risk, market
TECOP	Technical, environmental, commercial, operational, political
VUCA	Volatility, uncertainty, complexity, ambiguity

The RBS is an extension of systems theory in that it provides a forum for multiple disciplines (e.g., engineering, procurement, safety, etc.) to identify the implications of events from various perspectives. This can be highly effective in the identification of project or portfolio risks because unidentified risks are unmanaged threats (Chapman 2001). The RBS is a hierarchical tree structure similar in format and utility to the widely used WBS. The WBS significantly influences the project management process by decomposing all project work packages into manageable levels of detail. Like the WBS, the RBS provides a structure on which the entire risk management process can be developed. In addition to providing structure, the RBS framework can enhance communication and transparency by organizing risk information in a standard format for oversight and reporting. All of the aforementioned frameworks (PESTLE, TECOP, etc.) shown in Table 5 are candidates for use in the development of a common risk management tool like the RBS.

Within the RBS framework, risks are decomposed to levels of increasing specificity, allowing for the development of detailed risk responses. Table 6 is an example of a generic RBS showing three levels of decomposition.

Table 6. Generic RBS framework (modified from Hillson [2003])

Level 0	Level 1	Level 2
Project risk	Technical	Scope definition Requirements definition Technology Reliability
	Management	Organization Resourcing Communication
	Commercial	Contractual terms and conditions (T&Cs) Financing Payment terms
	Political	Regulations Elections

Level 0 simply identifies the overall content of the tree structure; in this instance, it is project risk. Level 1 is the overall project risk framework, which is usually determined by company procedure or using one of the aforementioned frameworks (Table 5) that fits the project context. Level 2 identifies the next level of detail (and so on) until the specific risks are defined to the level required for preparing an effective response plan. While this framework is useful, there is an underlying assumption that risks are independent of the risk factors and remain that way throughout time (Chapman 2001). Once the RBS is completed to the appropriate level of decomposition where cause and effect can be articulated, then risk statements can be developed using the generic structure: “Because of <one or more causes>, <risk> might occur, which would lead to <one or more effects>” (Hillson 2006). However, there is not a conspicuous category for behavior-centric intangible risks in any of these frameworks.

In the existing frameworks, there are several social or sociocultural categories, but none provides prompts to assess intangible factors (e.g., implications of outsourcing on team motivation). While the general nature of these frameworks can provide flexibility for project teams to apply them to their specific circumstances, there is no direct prompt with regard to behavior-centric intangibles as a potential risk to meeting objectives. This is a gap—the ability to proactively address intangible factors like respect, trust, and openness in a systematic way early in the project cycle is necessary for robust risk management (Uher and Toakley 1999). Therefore, a risk framework that specifically highlights these characteristics has the potential to enhance a project’s ability to meet its objectives.

Behavior-Centric Intangible Risk Assessment in Projects and Portfolios

Intangible Risk Breakdown Structure

Extending the concept of the RBS to include behavior-centric intangible risks requires the development of a framework identifying behavioral categories capable of materially impacting the overall effectiveness of project stakeholder interactions. The literature is replete with research regarding behaviors in the context of teamwork. While not exhaustive, Table 7 presents six emergent focus areas.

Table 7. Behavior-centric risk focus areas for this research

Focus area	References
Trust	(Atkinson 1999; Bankolli and Jain 2014; Chinowsky et al. 2008, 2011; Clark-Ginsberg 2017; Lencioni 2007; Levin and Wyzalek 2015; OGA 2017; Salas et al. 2015; Uher and Toakley 1999)
Conflict	(Bankolli and Jain 2014; Beringer et al. 2013; Brockman 2014; Gardiner and Simmons 1992; Jonas 2010; Jonas et al. 2013; Lencioni 2007; Long et al. 2013; Min et al. 2018; Osei-Kyei et al. 2019; Repenning and Sterman 2001; Roth and Senge 1996; Salas et al. 2015; Thamhain and Wilemon 1975)
Commitment	(Belassi and Tukel 1996; Chapman 2001; Lencioni 2007; Roth and Senge 1996; Salas et al. 2015),
Accountability	(Jonas 2010; Lencioni 2007; Levin and Wyzalek 2015; OGA 2017; Tartell 2017)
Results	(Chinowsky et al. 2008; Lencioni 2007; Roth and Senge 1996)
Empathy	(Ganegoda and Bordia 2019; Walther et al. 2017)

According to Bordage, robust conceptual frameworks should be based on "sets of concepts, or evidence-based best practices derived from outcome and effectiveness studies" (Bordage 2009). The behavior-centric elements in Lencioni's book *The Five Dysfunctions of a Team* can be considered in light of this qualification. Lencioni's book has sold more than three million copies, and the five dysfunctions framework is widely used by management consultants to assess corporate organizational effectiveness. The researcher has worked with global management consultants using this framework to assess team behaviors. Lencioni addressed five of the six focus areas identified in the aforementioned high-level literature search: trust, conflict, commitment, accountability, and results. There are varying definitions in the literature for each of these risk areas; however, for the purpose of this study, the following definitions are used:

- *Trust*: "The confidence among team members that everyone's intentions are 'good' and there is no reason to be 'protective or careful' – comfortable to share concerns, need for help, mistakes, lack of understanding. In other words, the energy is focused on delivery not being disingenuous or political" (Lencioni 2007).
- *Conflict*: "Level of willingness to engage in productive, unfiltered debate that ultimately leads to discomfort, stress, and growth" (Lencioni 2007).
- *Commitment*: "Teams make clear and timely decisions and move forward with complete buy-in from every member of the team, even those who voted against the decision. They leave meetings confident that no one on the team is quietly harboring doubts about whether to support the actions agreed on" (Lencioni 2007).
- *Accountability*: "The willingness of team members to call their peers on performance or behaviors that might hurt the team" (Lencioni 2007).
- *Results*: "Team members do not put their individual needs (such as ego, career development, or recognition) or even the needs of their divisions above the collective goals of the team" (Lencioni 2007).

This structure provides a basis for the development of a behavior-centric intangible risk structure (IRBS) to assess the issues that emerge from adaptation to the dynamic environment of projects and project portfolios.

The proposed IRBS (Table 8) is a tree structure describing the presence or absence of each risk factor. The three levels (0, 1, 2) provide an increasing level of detail so that effective risk response plans can be developed (Hillson et al. 2006), with Level 0 being the overall risk.

The IRBS is considered a checklist to be used in project or project portfolio workshops and should be customized for specific project circumstances.

Table 8. IRBS from Lencioni's *The Five Dysfunctions of a Team*

Level 0	Level 1	Level 2
Behavior-centric intangible risk	Trust	Conceals or admits weakness and mistakes
		Hesitates to ask or asks for help or provides constructive feedback
		Rushes to a conclusion without clarification about intention or gives benefit of the doubt
		Recognizes or fails to recognize and tap into others' skills and experiences
		Wastes time and energy managing behaviors for effect or focuses on important issues not politics
		Hold grudges or gives/accepts apologies without hesitation
		Finds reasons not to or to engage meaningfully
	Conflict	Holds ineffective or meaningful meetings
		Creates environments where back-channel politics and personal attacks thrive or minimizes/eradicates politics
		Ignores or addresses controversial topics critical to team success
		Fails to tap into all the opinions and perspectives of team members or ensures all critical topics are discussed
		Wastes time and energy with posturing and interpersonal risk management or surfaces disagreements
	Commitment	Supplies vagueness or clarity among the team about direction and priorities
		Misses deadlines and opportunities because of excessive analysis and delay or aligns team around common objectives
		Breeds lack of confidence and fear of failure or learns from mistakes
		Revisits discussions and decisions again and again or moves forward without hesitation
		Encourages second-guessing and distancing among team members or makes needed changes without hesitation
	Accountability	Creates resentment among team members who have different levels of performance or actively encourages improvement
		Encourages mediocrity or identifies problems quickly and holds team to the required level of performance
		Misses or meets deadlines and key deliverables
		Places undue burden on the leader as the sole source of discipline
	Results	Is or is not proactive
		Encourages individuals to or to not primarily support their group or themselves
		Has more successful results than missed targets
		Will or will not bear an extra burden of another group even to benefit the organization
		Is easily distracted and inwardly focused or is always looking to add value

Causal Factors

Identification of and methods for proactive response to early warning signs can be found in publications and websites across various business sectors; however, they have rarely been discussed in the project management literature (Haji-Kazemi et al. 2013, 2015). Early warning as a concept is generic and can be applied to almost any set of circumstances where a need exists to have insight as early as possible with regard to some future occurrence. Like risk, early warning signs usually carry a negative connotation (Nikander and Eloranta 2001), and an organization's culture or an individual's bias may impact the ability to recognize these important signals (Haji-Kazemi et al. 2015).

Causal factors like early warning signs can provide the project team with an indication of potential behavior-centric risk responses. Causal factors are occurrences that can affect human behavior and initiate a sequence of mental and emotional reactions as people attempt to make sense should unplanned changes or issues arise in the working environment (Isabella 1992). In the project context, politics (Haji-Kazemi et al. 2015), misaligned project objectives (Beringer et al. 2013), unclear or overlapping role requirements (Klakegg et al. 2011), and conflicting interpretations of policies and procedures (Thamhaim and Wilemon 1975) are examples of causal factors. These can lead to interpersonal friction or "wicked messes" (Roth and Senge 1996), with the potential to result in a cascading effect where problems are compounded throughout the project development cycle. A checklist of causal factors from various literature sources (Brockman 2014; Gardiner and Simmons 1992; Hofman et al. 2017; Liew n.d.; Symonds 2011) is shown in Table 9. This list and the definitions are intended for use in project- or portfolio-specific workshops where the stakeholders are free to modify the content and definition to fit the local project or portfolio conditions.

Table 9. Causal factor checklist

Causal factor	Definition
Lack of management commitment	Ongoing active support is not obvious to the project team
Improperly defined priorities	Lack of clear management directive on the priorities for project team deliverables
Poorly defined roles and responsibilities	Stakeholder roles and responsibilities not clearly defined, communicated, and agreed
Team weakness (composition)	Missing or inadequate required skill sets on the project team
End-user expectations	End user has not clearly communicated and documented conditions of satisfaction, and changes must be mutually agreed by impacted stakeholders
Inappropriate risk tolerance	Delays caused by reluctance to make necessary decisions
Misaligned or overlapping objectives	A stakeholder's objectives intrude on or are opposed to those of other stakeholders
Undefined objectives and goals	Lack of complete clarity regarding project objectives and goals
Poorly defined scope	Scope is not properly detailed for effective delivery
Inadequate or vague requirements	Requirements that can have multiple interpretations or lack necessary details
Competing priorities	Stakeholder groups' priorities are misaligned or in conflict
Poor communication	Channels of communication are ineffective
Culture	Project context is conducive for project team to succeed
Lack of necessary authority	Authority is not commensurate with responsibility
Business politics	Specific interests take precedence over what is best for the business or power is challenged
Interpersonal conflict	Conflict has gotten personal and creates adverse implications to accomplishing the project
Lack of organizational support	Project needs are not acknowledged by organization

Because organizations can be at different levels of project management maturity (Barber 2005), the causal factor checklist can be reviewed with appropriate SMEs and modified as needed to align with the organizational context. This customized list of causal factors was used in the project risk workshops for this research.

Risk Inducement Matrix

The RIM (Table 10) is an adjacency matrix created by combining the most detailed level of intangible risks from the IRBS and the list of risk causal factors. The RIM provides a way to address system complexity by providing a means for mapping multiple events interacting with multiple risk factors. Additionally, it provides a means to address the topic of behavior in a structured way. The Level 2 risks from the IRBS (e.g., conceals weakness and mistakes) are listed along the x-axis (IRF1, etc.), and the appropriate causal factors are listed along the y-axis (RT1, etc.). The RIM is used in risk workshops with project teams to identify the events that are likely to instigate an intangible risk factor in the project’s particular context. Once complete, the RIM provides a perspective of the extent to which the risk causal factors influence risk events. Some of the causal factors can be caused by shortcomings in corporate policies and procedures, while others stem from behaviors (Barber 2005; Isabella 1992). The RIM is a tool for project teams to use in project risk meetings, as well as input for system analysis modeling.

Table 10. RIM

	IFR1	IFR2	IFR3	IFR4	….	….	IFRx
RT1	x						
RT2				xx			
RT3		xx		x			
RT4	x		xx				
RT5			xxx				
RT6	xxx	xx		x			
:		x					
:	x			x			
RTy							

Process for Implementation

The process to gather and validate the necessary risk and causal factor information can be done as part of a project risk workshop or in a dedicated workshop with the key project stakeholders. SMEs are required for review and validation of the information. The seven steps used in the IRAMP process in this research are detailed in the following sections.

Step 1: Initial Information Gathering

Structured interviews with key stakeholder management and senior staff were used to identify various perspectives regarding potential causes of the performance gap. The interviews took place in the interviewee's office with the interviewee, researcher, and management-appointed observer. One week prior to the start of the interviews, a preread document was distributed. This document contained the following information: purpose of the interview, data supporting the purpose, and diagnostic questions (what is going well, what is not going well). During the interview, comments regarding behavior (e.g., conflict, lack of teamwork) were further probed regarding how the behavior has manifested itself and the potential root causes. A general list of causal factors from the literature was used for prompts in the interviews. The information was consolidated, and key themes were presented to management with a recommendation to gather information from a broader sector of the stakeholder population using a survey. Management was asked to assign an SME focal point from each stakeholder group to support the process.

Step 2: Subject-Matter Expert Workshop

The purpose of the SME workshop was to review the IRBS, causal factor checklist (from literature and interviews), and metanetwork for completeness and endorsement. Dialog among SMEs representatives from all stakeholder groups proved foundational for achieving consensus. In the workshop, the IRBS and causal factor checklist were discussed in the context of the project development context, with Level 2 risks being the focus of the discussion. Any changes to the IRBS or causal factor checklist were required to be supported by the SMEs and documented. The final task in Step 2 was formal validation by the SMEs of the IRBS and causal factors to be used in the workshops with project teams and other stakeholders.

Step 3: Information Verification

A survey was developed based on the behavioral dimensions agreed on with management and was distributed to the sample population. The survey population consisted of participants from all stakeholder organizations, as well as all levels below senior management. A Likert scale was used for responses ranging from “strongly agree” to “strongly disagree.” Organization charts and responsibility matrices from projects, as well as feedback from management and SME focal points, served as the basis for the survey participant selection.

Step 4: Survey Analysis and Validation

Survey responses were translated into a heat map to establish the areas for more focused assessment. Level 2 risks were used to populate the RIM (Table 10), along with the consolidated list of causal factors from Step 1. A validation session was held with SMEs to (1) review the survey results and RIM to gain alignment, (2) develop a list of project stakeholder teams from recently completed and ongoing projects to participate in workshops, and (3) present results and recommended workshops to management for support.

Step 5: Project Team Workshops and Data Consolidation

Workshops for all selected projects were scheduled (ca. four hours in length), requiring attendance from representatives from all stakeholder groups. Each selected project team was asked to prepare a list identifying deliverables and/or objectives not meeting expectations. The metanetwork was presented, and the people × people and people × task networks were reviewed. In the next portion of the workshop, the team used the RIM to identify the risks and causal factors contributing to the eventuating risk. The final session in the workshop was intended to identify potential mitigations to the causal factors.

Step 6: Initial Assessment and Recommendations

Behavior-centric intangible risk and intangible risk causal factor information gathered from the project team workshops was cataloged as either project-specific or portfolio-specific by stage. The causal factors were then classified as either requiring management intervention or clarification. The recommended mitigations from the project team workshops were aligned with the appropriate causal factors. This information was then presented to management for information and further deliberation.

Step 7: Decision Support Analysis

The metanetwork (Chapter VI) for each project was simulated using commercially available MNA software. Scenarios were developed to explore the project team–recommended mitigations to (a) identify key people (e.g., position in the network, workload, influence on causal factors, ability to influence network, etc.), (b) identify influential causal factors and behavior-centric intangible risks, and (c) identify organization enhancement opportunities. This process, like the IRBS and causal factor checklist, should be adapted to the particular circumstances of the project or project portfolio environment.

Conclusions

The current RBS approach is robust for systems where cause and effect can be adequately predicted (i.e., simple and complicated systems). However, as systems become complex with emergence and adaptation becoming more pronounced, the RBS requires enhancement. In the context of behavior-centric intangible risks, this is accomplished by implementing IRAMP. The IRBS, causal factor checklist, and RIM provide a means to customize the causal factors and behavior-centric intangible risk factors for each project's particular circumstances, as well as allowing visualization of the relationships or the network between behavior-centric intangible risks and causal factors. The resultant networks and the risk-risk, causal factor–risk, and causal factor–causal factor interrelationships were defined in a workshop and served as inputs to MNA.

CHAPTER VI

METANETWORK ANALYSIS AND MEASURES

Context

In Chapter V, the behavior-centric risk data collection conceptual and methodological frameworks were presented. This chapter presents the conceptualization and methodology for the metanetwork structure and the appropriate analytical measures. The terms network of networks and system of systems are used interchangeably. Rasmussen's dynamic model of safety and system performance served as the progressive genesis for the development of the behavior-centric intangible risk–based metanetwork construct. MNA is presented, along with the results of an industry SME validation workshop.

Conceptual Framework

Sociotechnical System of Systems

In Chapter III and Chapter IV, Rasmussen's dynamic model of safety and systems performance (Figure 6) was presented. His model is based on the premise that functional abstraction is more appropriate than structural decomposition as a means to assess sociotechnical systems. Rasmussen conceptualized the interactions among management, the workforce, and the prevailing safety culture as interacting gradients influencing the way a facility is operated (in the "space of possibilities") (Rasmussen 1997).

The dynamic model of safety and system performance can be characterized as a metanetwork (a network of networks). Representing the conceptual model in this format provides access to existent social network measures and a way to link the model to data. In doing so, complexity can be quantified in terms of components and relationships (Carley 2002). The elements of the systems are management, worker, task, and safety culture. As an example, management instigates the gradient toward efficiency by setting productivity requirements for the workers. Implicitly, there is interaction among members of management with regard to setting goals and objectives, as well as management and tasks through procedural requirements. Management interacts with safety culture by setting operating standards. Table 11 translates Rasmussen's conceptual framework into a network of networks.

Table 11. Representation of Rasmussen's model as a network of networks (adapted from Rasmussen [1997])

Entity	Entity	Interaction
Management	Management	Planning and target setting
Management	Task	Procedural requirements
Management	Safety culture	Error margin
Management	Worker	Increased efficiency
Worker	Worker	Task delivery
Worker	Task	Level of workload
Worker	Safety culture	Challenge to boundary
Task	Task	Dependency
Task	Safety culture	Performance boundary
Safety culture	Safety culture	Reinforcement

Carley asserted that organizations are "composed of intelligent adaptive agents who are constrained and enabled by their positions in networks linking agents, knowledge, resources and tasks" (Carley 2002). This linking of agents to tasks, knowledge, and resources extends the homogeneity of social networks to a heterogeneous network of networks—the metanetwork. This metanetwork is an aggregation of tangible elements (agents) and intangible elements (knowledge). Consequently, the metanetwork is defined as a network of networks (Carley et al. 2007). Therefore, Rasmussen's model can be presented in the metanetwork construct shown in Table 12.

Table 12. Metamatrix of Rasmussen's model (adapted from Rasmussen [1997])

	Management	Worker	Task	Safety culture
Management	Planning and target setting	Increased efficiency	Procedural requirements	Error margin
Worker		Task delivery	Level of workload	Challenge to boundary
Task			Dependency	Performance boundary
Safety culture				Reinforcement

Projects face a dynamic similar to Rasmussen's safety and system model where multiple influential elements (gradient toward efficiency, gradient toward least effort, countergradient for safety culture) exist within the overall delivery network. Rasmussen's model of the plant operating environment is analogous to the project environment in that both have economic, agent, and performance dimensions. Extending his model to projects (Figure 8 in Chapter IV), the boundaries become commercial, human effort, and task performance. The commercial boundary can be defined as the project objectives set at the time of funding in terms of cost, schedule, and scope. The human effort sets the limit of the existing human resource ability to work effectively given the direct workload and the potential added requirements of workflows (e.g., approval process), procedures (e.g., differing interpretations or expectations), and existence of required competencies. The margin of tolerance can be viewed as the contingency in the system to address knowable uncertainties (known-unknowns), and a breach of the acceptable task performance boundary is the point where project objectives are adversely impacted. In this research, the margin of tolerance is defined as the zone where the pressure from the stakeholders for delivery and the project team ability to manage the workload exceed the existing performance culture, and an unacceptable event occurs that impacts project performance. This dynamic can be framed in the generalized risk description language proposed by Hillson: “Because of one or more conditions caused by stakeholder or project team <causal factor>, a behavioral response <risk> might occur, which would lead to an impact on project objectives <one or more effects>” (Hillson 2006). Taking the Rasmussen framework to the next level of detail requires adding a behavioral dimension to the forces that impacts the location of the project delivery vis-à-vis the task’s acceptable performance boundary.

Recognizing that the dynamics of human behavior are nonlinear and can undergo “qualitative changes when a parameter exceeds a critical value” (Huys and Jirsa 2011), “it’s impossible to build a theory of nonlinear systems” (Hardesty 2010). The ability to integrate project management and SNA can provide a means to move from the current reductionist risk management techniques to a more holistic calculus (Chinowsky et al. 2008). Existing SNA measures can provide a means to quantify the human behavior dimension of projects and provide structure for addressing these softer or nontechnical issues (communication, trust, etc.) in a systematic way. The resultant effects of this approach can lead to enhanced project and portfolio performance through the development of high-performance teams (Chinowsky et al. 2008; Sanchez et al. 2009). To achieve this, a project or project portfolio is conceptualized as a series of dynamic interacting networks of people, activities, tasks, and events that have the potential to change throughout the project development cycle. Continuing in this line of reasoning, a network can be thought of as any interaction between entities, such as project stakeholders among themselves, project stakeholders and causal factors they may activate, or the relationship between people and the tasks they perform. Integrated workflows and multiple interfaces between people and activities create a complex environment for communication and building trust (Hartman 2000). This complexity can lead to stakeholders having differing perceptions and expectations regarding project and portfolio requirements and outcomes (Morton et al. 2006). These interdependencies and potential differing expectations create dynamic portfolio-level risks that are different than project risks. Risks of this kind are nonlinear and can exhibit highly random behavior (Carley et al. 2013; Danilovic and Sandkull 2005; Floricel and Ibanescu 2008; Hofman et al. 2017; Teller and Kock 2013).

Behavior-centric intangible risk in projects and project portfolios can be conceptualized as a dynamic network of networks made up of the following entities: (a) people involved in the project throughout the development cycle or stages, (b) deliverables or tasks, (c) behavior-centric intangible risk factors, and (d) events or conditions that can cause the risk to occur. The conceptualization of the network of networks is shown in Figure 9.

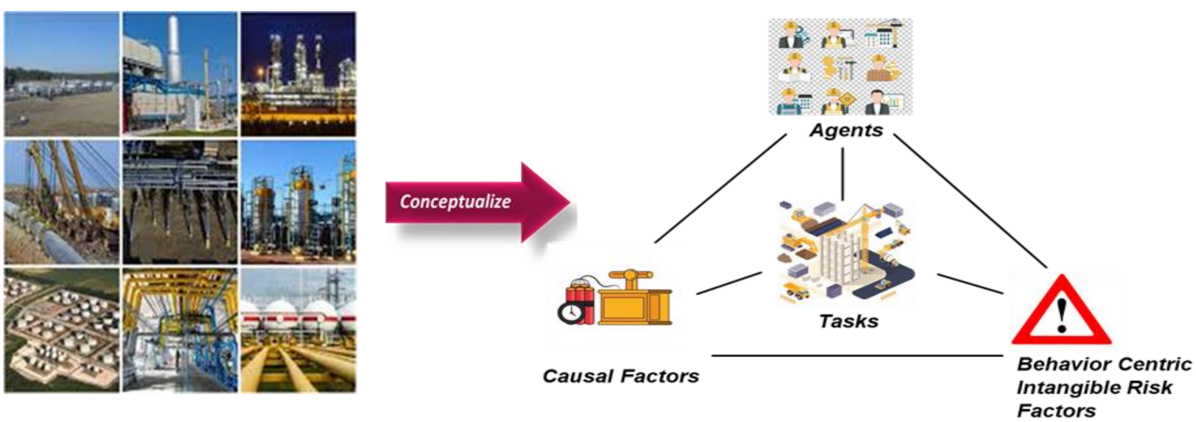


Fig. 9. Conceptual model of project behavior-centric intangible risk interaction (modified from Zhu [2016]).

Rasmussen's conceptual model provides a bounded system in which adaptive behaviors are generalized as subjective preferences. However, Rasmussen recognized the gap in his model when he stated, "We need a framework for identification of the objectives, value structures, and subjective preferences governing the behavior within the degrees of freedom faced by the individual decision maker and actor" (Rasmussen 1997). To address this gap, the project behavior-centric intangible risk interaction model (Figure 9) is integrated with the dynamic model of project performance and behavior (Figure 8 in Chapter IV), resulting in a nested system of systems (Figure 10). In this nested system, the dynamic interactions (gradients) are similar to Rasmussen's model. In the nested system, the commercial requirements of meeting cost, scope expectations, and schedule press against the project team's interpretation of requirements and established work plans. The performance culture is a countervailing gradient to keep the team focused on meeting the project objectives. The gradients are catalysts for initiating causal factors in the behavior-centric intangible risk subsystem of systems. Once this takes place, the interactions among causal factors, agents, risk factors, and tasks emerge.

Incorporating the behavior-centric intangible risk model within the Rasmussen framework provides a basis to develop a system-of-systems calculus to quantify what he referred to as "idiosyncratic and unpredictable" behaviors. This analytical construct is focused on understanding the consequences of seemingly innocuous decisions to deviate from a standard activity that can lead to an unwanted performance event (Rasmussen 1997). The interactions within the behavior-centric intangible risk metanetwork (network of networks) arise from organizational or interpersonal events (Isabella 1992), leading to adaptive behaviors in the agents. This dynamic can impact the project team's ability to meet project task objectives (Brockman 2014) or, said another way, breach the acceptable performance boundary. The behavior-centric intangible risk can be described as the set of networks shown in Table 13.

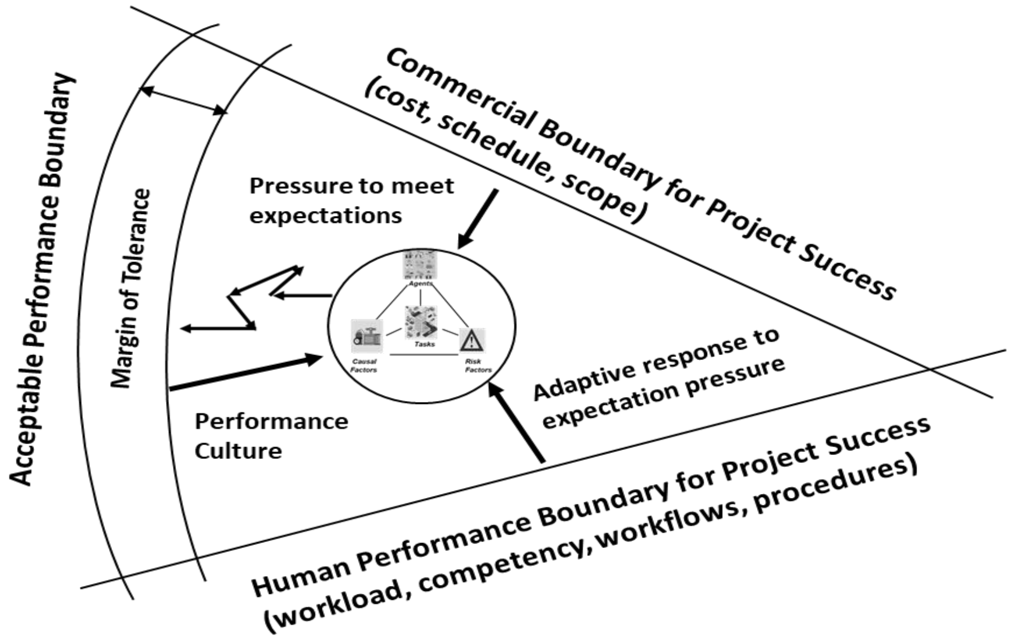


Fig. 10. Extension of dynamic model of safety and system performance to project performance incorporating behavior-centric intangible risk (adapted from Rasmussen [1997] and Zhu [2016]).

Table 13. Project behavior-centric intangible risk networks

Entity	Entity	Interaction
Agent	Agent	Communication
Agent	Causal factor	Activation
Agent	Intangible risk factor	Influence
Agent	Task	Assignment
Causal factor	Causal factor	Dependence
Causal factor	Intangible risk factor	Inducement
Causal factor	Task	Impedance
Intangible risk factor	Intangible risk factor	Dependency
Intangible risk factor	Task	Contagion
Task	Task	Interaction

Metanetwork

The metanetwork is a framework that is useful in representing the interactions among various networks. The fundamental building blocks of networks are nodes that can represent tasks, agents, information, resources, etc. in organizations, and their interactions are referred to as links (Carley 2002). An advantage of this approach is the ability to analytically quantify and visually display complex behavioral interrelationships (McCulloh and Carley 2008). Human behaviors and mental frameworks are themselves dynamic nonlinear systems (Afraimovich et al. 2011). This accentuates the importance of understanding behavior-centric intangible factors that influence the project in ways that are difficult to quantify. These risks can manifest themselves in human interactions, such as ability to adapt, appropriate application of experience, communication, cooperation, culture, teamwork, relationships, leadership, and conflict resolution (Bankolli and Jain 2014; Deloitte Center for Energy Solutions 2015; Nogeste and Derek 2008; Thamhain and Wilemon 1975). In the study of the dynamics of human behavior, researchers have observed that human systems are nonlinear and can undergo "qualitative changes when a parameter exceeds a critical value" (Huys and Jirsa 2011). Dr. Pablo Parrilo of the Massachusetts Institute of Technology (MIT) went on to conclude that "it's impossible to build a theory of nonlinear systems, because arbitrary things can satisfy that definition" (Hardesty 2010).

The proposed metanetwork matrix (Table 14) comprises the aforementioned 10 interconnected networks, providing a framework to assess the emergence of behavior-centric intangible risks in the project and portfolio context. These networks represent the interactions among the four elements: agents (stakeholders), behavior-centric intangible risk factors, causal factors, and tasks. The development of each of the networks relies on input from IRAMP, stakeholder feedback, and a project-specific document. However, depending on the unique context of the project or portfolio setting, some of the networks may not be relevant.

Table 14. Metanetwork matrix

	Agent	Causal factor	Intangible risk factor	Task
Agent	Communication network: who interacts with whom	Activation network: who “lights the fuse”	Influence network: who is likely influenced by which risk factor	Assignment network: who is involved (input/review) in which task
Causal factor		Dependence network: causal factor–causal factor interaction	Inducement network: causal factor influence on intangible risk	Impedance network: causal factor impact on task
Intangible risk factor			Correlation network: which risks are mutually exclusive and which interact with other risks	Contagion network: which tasks are impacted by which intangible risk
Task				Interaction network: task interactions with other tasks

Methodological Framework

The conceptual framework was implemented utilizing a combination of existing project tools and IRAMP. The metanetwork assessment had three phases: (1) creation of the detailed subnetworks from existing project documents, project workshops, and the RIM, (2) simulation of the metanetwork, and (3) identification of appropriate network analysis measures.

Subnetwork Construct

Network science has its genesis in graph theory and has emerged as a means to understand how network properties affect network behaviors. Networks are made up of components (e.g. agents, tasks, etc.) called nodes or vertices, and how they interact is shown by connections called links or edges (Barabási 2016). An example of a simple network is shown in Figure 11, with N being nodes and L being links.

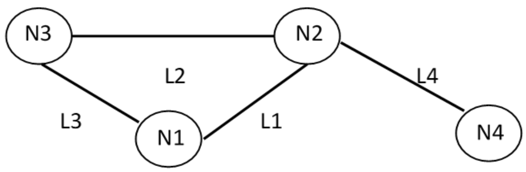


Fig. 11. Simple network consisting of four nodes and four links.

Each of the subnetworks can be represented as an adjacency matrix. An adjacency matrix provides a visual representation of the interactions between the nodes in a graph. The nodes are connected by links, and this connection is indicated by an entry of 1. The rows contain the outgoing links from the node of interest, and the columns contain the incoming links to that node. If there is a link connecting two nodes, they are considered adjacent, and an empty cell means that there is no interaction. Table 15 is indicative of a network adjacency matrix.

Table 15. Adjacency matrix for agent × agent network

	Agent 1	Agent 2	Agent 3	Agent 4	….	….	Agent x
Agent 1		1					
Agent 2				1			
Agent 3	1						
Agent 4			1				
:							
:							
Agent x							

Subnetwork Population

The data for developing the subnetwork adjacency matrices came from two sources, existing project documents and workshops with project teams and SME reviews. The data sources for each of the subnetworks are shown in Table 16. The data collection and adjacency matrix development took place in two phases. The first phase used the responsibility matrix, organization charts, and WBS to populate the agent × agent, agent × task, and task × task subnetworks. In the second phase, workshops were held with project teams to populate the balance of the subnetworks.

Table 16. Subnetwork data sources

Network	Information source
Agent × agent	Responsibility matrix and organization charts
Agent × causal factor	Stakeholder workshop
Agent × intangible risk factor	Stakeholder workshop
Agent × task	Responsibility matrix
Causal factor × causal factor	Stakeholder workshop
Causal factor × intangible risk factor	Stakeholder workshop
Causal factor × task	Stakeholder workshop
Intangible risk factor × intangible risk factor	Stakeholder workshop
Intangible risk factor × task	Stakeholder workshop
Task × task	WBS

Responsibility matrices (or responsible-approve-comment-inform [RACI] charts) and corporate organization charts served as the basis for constructing the communication and assignment networks. RACI charts (e.g., Table 17) and a firm's organizational chart (e.g., Figure 12) are important to ensure efficient work allocation and clear accountabilities for tasks (Costello 2012). The communication network (agent × agent) focuses on how the stakeholders or agents interact with each other in the project context. These interactions can differ from project to project or within each development stage of a particular project. The combined information from the organizational and RACI charts identify these interactions.

Table 17. RACI chart example

	Procurement	Operations	Technical services	HSE	QA/QC	Engineering design	Project controls	Project management	Construction management	VP technical services
Manage project controls	I					C	R	A	C	
Implement QA/QC plan	I	I	C		R	A		I	I	
Maintain risk register	I	I	I	C	C	C	R	A	C	I
Issue construction packages	R	I	C	I	I	I	I	C	A	
Implement commissioning plan		A		I		I	I	R	C	
Red-line construction drawings		C	C		I	R		A	C	

Notes. HSE = health, safety, and environment; QA/QC = quality assurance / quality control; VP = vice president

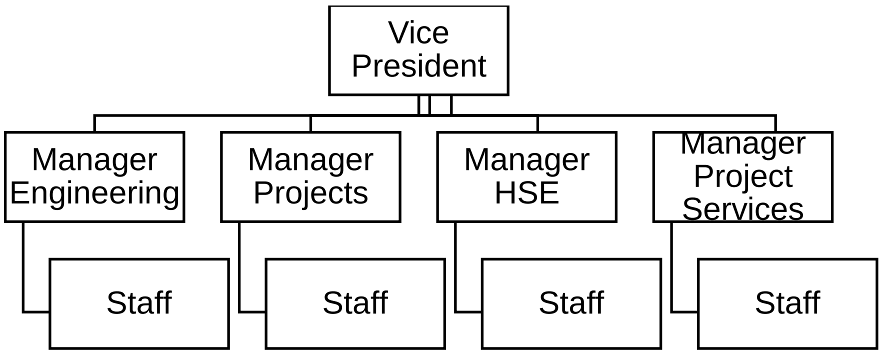


Fig. 12. Generic organization chart.

RACI charts are ubiquitous in the practice of project management. An RACI chart is a matrix of all the tasks in a project with links to all the stakeholders who are involved. At each intersection of activity and stakeholder, the role is identified as being responsible for, approving, commenting on, or being informed regarding a particular task. A detailed responsibility matrix (RACI) identifies the human resources assigned to each task and illustrates the interactions among them. This information was used in this research to develop the assignment subnetwork (agent × task). In a portfolio, the responsibility matrix can be used to identify the roles of various departments in project work packages. The responsibility matrix can be useful in clarifying roles and responsibilities or identifying potential issues, such as too many resources assigned to a particular task (PMI 2017; Tartell 2017). The definitions for the roles are as follows:

- *Responsible*: Stakeholder(s) who do the work to complete the task
- *Approve*: Stakeholder who approves the task and is ultimately accountable for the successful completion of the task
- *Comment*: Stakeholder(s), usually SMEs, who are required to provide input
- *Inform*: Stakeholder(s) who have no accountability for the task but are to be kept up to date on the activity

The WBS (e.g., Figure 13) served as the basis for completing the interaction subnetwork (task × task) adjacency matrix. The WBS decomposes the overall project to a collection of work packages (tasks) using a hierarchical structure. The WBS is an essential tool for effectively organizing the work, identifying the resource requirements, and developing the project schedule (PMI 2017).

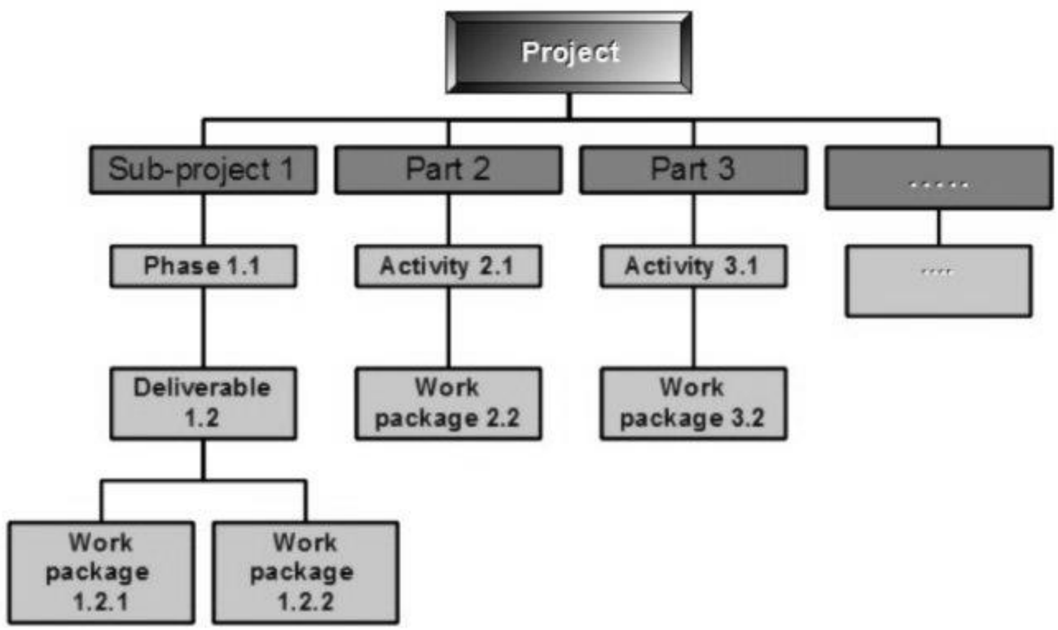


Fig. 13. Generic WBS.

The balance of the subnetworks focused on the behavior-centric intangible risks, their causal factors, and the interactions with agents and tasks. This information was specific to the environment experienced by the particular project stakeholder group. Workshop attendance was required for all relevant stakeholders with the intent of sharing knowledge and identifying and solving problems. The completed adjacency matrices are the deliverables from the workshops.

The initial focus of the workshop was to customize the IRBS and list of causal factors; once this was complete, the RIM was populated. In addition to providing a prioritization of causal factors and behavior-centric intangible risks, the RIM provided the information to complete the provocation subnetwork (causal factor × behavior-centric intangible risk). The balance of the networks (Table 14) is as follows:

- *Activation subnetwork (agent × causal factor)*: Identifies which stakeholders are capable of influencing which of the causal factors and highlights the need to ensure that all high-influence stakeholders are appropriately involved and communicated with.
- *Contagion subnetwork (behavior-centric intangible risk × task)*: Identifies which behavior-centric intangible risk factors impact which tasks. Behaviors impacting tasks on or near the critical path can be proactively managed.
- *Dependence subnetwork (causal factor × causal factor)*: Identifies which causal factors interact with each other and may also provide insight regarding which factor has the ability to influence the highest number of other causal factors.
- *Influence subnetwork (agent × behavior-centric intangible risk factor)*: Identifies which behavior-centric risk factors are likely to be exhibited by which of the stakeholders.
- *Correlation subnetwork (behavior-centric intangible risk factor × behavior-centric intangible risk factor)*: Identifies which intangible risk factors interact with other intangible risk factors and may also provide insight regarding which factor has the ability to influence the highest number of other risk factors.
- *Impedance subnetwork (causal factor × task)*: Identifies which causal factors have a direct effect on a task.

The completed subnetworks served as the input to the dynamic network analysis software package ORA-PRO.

Metanetwork Simulation

MNA is an area of study that integrates traditional SNA, link analysis, and multiagent systems. MNA combines the methods and techniques of SNA and link analysis with multiagent simulation techniques to assess complex and dynamic sociotechnical systems (Carley et al. 2007). MNA has been used in public health organizational effectiveness analysis (Merrill et al. 2007), terror network assessment (Carley et al. 2007), and project management (Li et al. 2015; Wang et al. 2018; Zhu and Mostafavi 2017). ORA-PRO is a commercially available analysis package designed to evaluate metanetworks in complex and dynamic sociotechnical systems. The genesis of ORA-PRO is the Dynamic Networks project at the Center for Computational Analysis of Social and Organizational Systems (CASOS) of the School of Computer Science at Carnegie Mellon University. The model is commercially available through Netanomics, an entity of Carley Technologies (Carley et al. 2013).

Network Analysis Measures

SNA investigates how different groups are connected and the frequency of those connections. These groups can be people, computers, ecosystems, or electrical power plants, and each of the individual members of the group is represented as a node. The connections in SNA are identified as links, so the networks formed by nodes and links can be country clubs, the internet, or a regional power grid, regardless of how they are connected; the frequency of connections is foundational for understanding the behavior of networks (Barabási 2016). In networks, there are nodes with varying levels of importance or influence. For instance, in a country club, some members sit on an advisory board with high influence, while others are rankand-file members. In this context, the board members are in a position to disseminate information more efficiently than ordinary members. These nodes can be viewed as having a differing degree of centrality, and several measures have been developed to identify a node with potential influence based on the number of inflows or outflows as compared to other members of the network (Rodrigues 2019). The algorithms to calculate these measures are an outgrowth of graph theory and calculate the importance of a given node within a network (Barabási 2016).

There are several measures of network centrality; those key to this research are highlighted. Degree centrality is a measure of the relative number of direct incoming and outgoing connections that a node has in a given network. The higher the count, the higher the likelihood a node is to receive and pass on critical information that flows through the organization. For node ni, the equation for degree ki is

$$\text{ki} = \sum_{j=1}^{N} \text{a(ni, nj)}$$

where a(ni, nj) is 1 if there is a connection between node ni and node nj and 0 if no connection exists. N is the number of nodes in the network being evaluated (Freeman 1978–1979). There are three measures of degree centrality, incoming degree ($k_i in$), representing the number of links that flow to node i, outgoing degree ($k_i out$), representing the number of links flowing from node i to other nodes, and a node's total degree (k_i) (Carley et al. 2013):

$$k_i = k_i in + k_i out$$

Betweenness centrality indicates the level to which a node is connected to other nodes and is the ratio of the shortest paths of all the nodes that pass through node i. The essence of this measure is that of frequency of flow through a particular node (Borgatti 2005). The equation for betweenness is

$$\text{Bi} = \sum_{j \neq k} pjk\ (i)\ /\ p_{jk}$$

where pjk (i) is the number of shortest paths connecting nodes j and k passing through node I, and p_{jk} is the total number of shortest paths connecting nodes j and k (Rodrigues 2019).

Eigenvector centrality is defined as the principal eigenvector of the adjacency matrix for the network being examined. A node with a high eigenvector value is one that is adjacent to nodes that have high eigenvector values. Conceptually, if a node influences just one other node, which subsequently influences many other nodes (which in turn influence other nodes), then the first node in that chain is one of critical influence because it can precipitate a cascading effect. Consequently, this measure is ideally suited to identify networks prone to propagation (e.g., power grid failure, spreading of disease). The equation of an eigenvector is

$$\lambda v = Av$$

where A is the adjacency matrix of the network graph, λ is a constant (the eigenvalue), and v is the eigenvector (Borgatti 2005).

Cognitive demand measures the total amount of effort expended by each individual or agent to perform the tasks in their remit. Individuals with high cognitive demand values are key individuals who can be disruptive to networks if removed or if at cross-purposes with other individuals in the network. Cognitive load is a complex measure accounting for the number of staff, resources, tasks the agent needs to manage, and communication needed to engage in such activity (Carley et al. 2013).

A potential boundary spanner is an individual in a position to connect groups or individuals isolated from other individuals or groups within the network being investigated. This individual is in a position to facilitate the flow of information or facilitate interactions (Long et al. 2013). This indicator is calculated using the ratio of betweenness centrality to total degree centrality (Carley et al. 2013). Table 18 describes the measures used in this research.

Table 18. Network analysis measures of centrality

Measure	Description	Use in this research
Total degree	Number of total links (inputs and outputs) to other nodes in the network. These are actors who have a broader understanding of the current and emerging ideas, thoughts, beliefs, etc. The higher the value, the more of a role the node plays in the context of the network.	This measure is important in identifying an agent's level of involvement and access to information regarding the "pulse" of the network.
Betweenness	How often a node appears as a bridge between nodes in the network. These actors facilitate efficient knowledge transfer, coordinate effort, or ensure inclusion of people on the periphery.	This measure is important to identify the actors who are important for effective information flow and can become effective "brokers." Additionally, they can be instrumental in building trust among groups that do not normally interact.
Potential boundary spanner	The degree that a node spans disconnected groups in a network.	This measure is important to identify actors who are in key structural positions capable of spanning organizational boundaries (silos, disciplines, etc.).
Eigenvector	A measure of the node influence on the entire network by having many connections to nodes with many connections.	This measure is important to identify the nodes that have the potential to underpin a network cascade. This can be effective in communication or propagation.
Out degree	Number of links to other nodes (outputs) in the network. The larger the number, the larger the effect on the network.	This measure is important to identify actors contributing to the completion of a task and/or influencing intangible risk causal factors, along with which causal factors can potentially influence the highest number of intangible risks.
In degree	Number of links from other nodes (inputs) in the network. The higher the number, the larger the effect by the network.	This measure is important to identify the causal factors and tasks most influenced by actors, as well as which intangible risks are influenced the most.
Cognitive demand	Measures the effort to perform tasks; the removal of this link can cause significant disruption.	This measure is used to identify the workload responsibility for each agent.

Subject-Matter Expert Validation Workshop

A workshop was held with a panel of energy industry SMEs to review and validate the IRAMP. This session was attended by 10 individuals with more than 300 years of combined project- and operations-related experience. The energy industry sectors represented were upstream oil and gas, midstream transportation and processing, downstream refining and chemicals, engineering design and EPC, global project management consultancy, and fabrication and construction contracting. The attendees ranged from chief operating officer (COO) to project director. The workshop covered the following topics:

(1) IRBS

(2) Risk causal factors and RIM

(3) Metanetwork and centrality measures

(4) Individual network reviews

(5) Insights and conclusions

The workshop was interactive, with questions and comments being addressed as the presentation progressed. At the end of the presentation, a feedback session was held, and the attendees were asked to complete an assessment form rating each of the topics as (a) very useful and ready for implementation, (b) useful with minor tweaks, (c) potentially useful after major revisions, or (d) not useful. The majority of the feedback was positive and supported the implementation of the IRAMP. Nine of the 10 attendees completed the assessment. The consolidated feedback is shown in Figure 14.

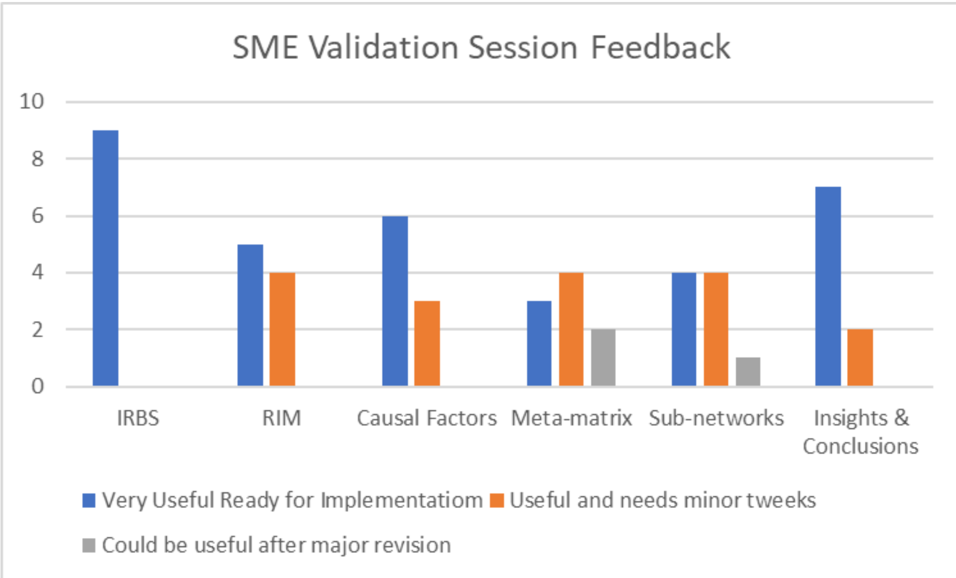


Fig. 14. SME validation session feedback.

The results and the final verbal feedback provided an independent validation of the research. The metamatrix and subnetworks had the widest distribution of responses. This is not surprising given that current approaches to risk management are linear and that conceptualization of risk in the context of a network of networks is not part of the standard project lexicon. The majority indicated the approach to be either useful or very useful, but noted that implementation would require effective communication and training of the existing workforce. All reported believing this approach to have the potential to add significant value. Several of the attendees asked if the researcher planned to continue this line of research because they felt that it could add significant value to the industry.

CHAPTER VII

CASE STUDY

Context

The goal of the case study was to assess IRAMP robustness in the context of an ongoing project and project portfolio environment. The objectives relating to IRAMP specifically in this organizational review of OilCo were as follows:

(1) Apply the IRBS, causal factor checklist, and RIM in an active project portfolio setting to identify and prioritize behavior-centric intangible risks for all stages of the project development cycle.

(2) Develop and analyze an actual organization applying a metanetwork construct using ORA-PRO simulation software. Also, identify network measures to quantify the behavior-centric intangible risks, agent attributes, and causal factor influences.

(3) Empirically validate IRAMP as a reasonable surrogate to holistically assess organizational modifications prior to implementation.

To provide an empirical basis for validation, IRAMP was implemented in an active project portfolio as follows:

(1) Gather initial information by interview and survey to identify and verify the behavior-centric opportunity areas to be focused on in the OilCo organizational review.

(2) Hold ex-post project assessment workshops with project teams and management to identify a baseline (what has happened and what is perceived to be the cause) of behavior-centric intangible risks and causal factors from an overall project perspective, and validate the data collection tools (IRBS, causal factor checklist, and RIM).

(3) Assess the behavior-centric intangible risks and causal factors for a portfolio of active projects (what has happened and what is perceived to be the cause) in various stages of the development cycle, and develop a metanetwork construct for each.

(4) Apply ORA-PRO network simulation software and SNA measures to identify organizational opportunities to enhance project and project portfolio performance.

(5) Make specific organizational and procedural recommendations to OilCo executive management to enhance project delivery performance

OilCo Project Delivery Performance

OilCo is an energy firm having company-operated (operated by OilCo) and non-company-operated (operated by other firms) assets in its global portfolio. Project delivery performance had not met the expectations of executive management regarding cost and schedule performance. During the period from 2010 to 2016, only 40% of projects were completed successfully (within +/– 10% of approved budget and schedule), with portions of the portfolio exceeding the original schedule by more than 100%. To address the gap, a study was commissioned to find out why projects were not performing to expectations. The researcher was a senior member of a working team formed to carry out the study. This working team was accountable to a steering committee comprising the OilCo executive team (all corporate executive vice presidents) to collectively review the progress, provide advice, and make necessary decisions. OilCo's project portfolio is executed by highly experienced technical teams adept at delivering similar projects in the various operated locations.

OilCo's organization is functionally based (e.g., operations, projects and engineering, finance, etc.), with the top of the reporting structure being executive-level vice presidents. This construct can be problematic when activities cross the organizational boundaries because there is not a mechanism for creating an ultimate single point of accountability with the appropriate level of decision-making authority below the level of the corporate president. In OilCo, three key stakeholder groups essential to project success were identified: the engineering and project execution division, the operations division, and the finance division. Based on initial exploratory discussions with executives from these three key stakeholder groups, the issues raised were both tangible and intangible. The tangible focus areas were identified as the corporate capital budgeting process, project selection process, management-of-change process, and project development process (stage gate). The intangible areas were identified as lack of effective teamwork, strained stakeholder group interactions, and effectiveness of communication regarding project requirements. The delays and cost overruns were attributed primarily to internal issues such as late changes after contract award, delayed handover of facilities to operations, and misalignment of priorities between the operations and project management organizations regarding resources; consequently, external stakeholders were not in the scope of the assessment. OilCo's delivery performance is illustrated in Figure 15, with the dashed rectangle highlighting the acceptable zone of delivery variance.

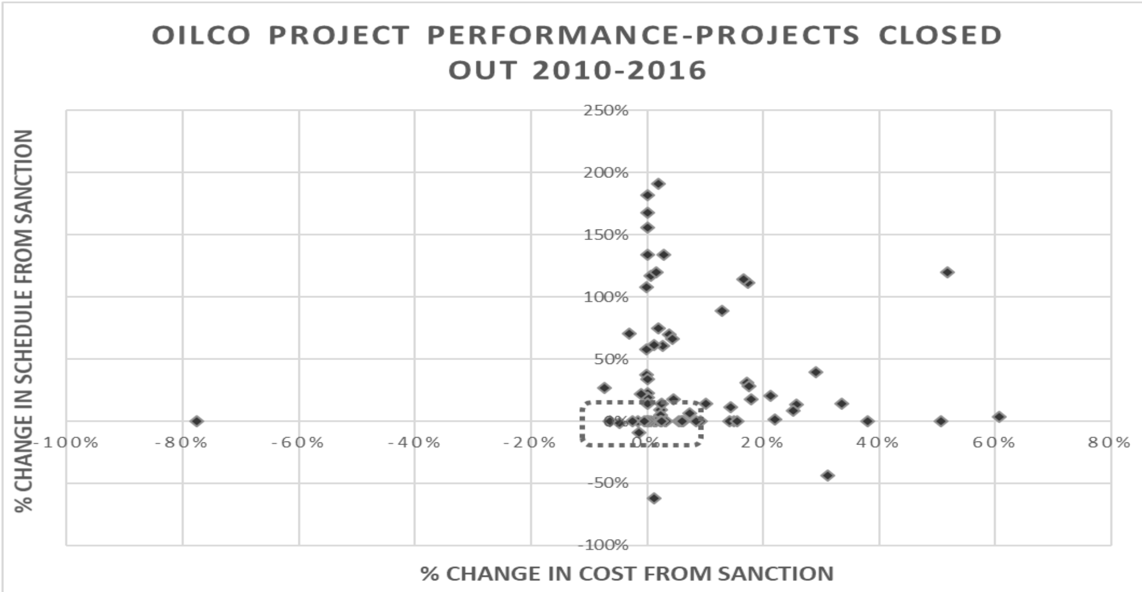


Fig. 15. OilCo project performance.

Interviews and Surveys to Validate the Issues

After the initial executive discussions, the decision was made to conduct semistructured interviews to validate the issues raised at the executive level. These interviews were held with 60 staff members (ca. 1% of total employee population in the key stakeholder groups) representing an appropriate organizational cross-section of the three divisions. The feedback regarding the intangible factors from these interviews strongly indicated misaligned objectives, lack of trust, reluctance to make decisions, ineffective meetings, and general reluctance to surface issues to senior management due to the “political” landscape. The feedback was consistent from all the stakeholder groups regarding the issues and their contributions to the project performance gap.

Addressing behaviors and the factors that precipitate them in any environment can be challenging—especially one with political overtones—and requires the use of methodologies with a proven history (Bordage 2009). The behavioral issues at OilCo closely aligned with the assessment framework in Patrick Lencioni's *The Five Dysfunctions of a Team*. The five areas are trust, conflict, commitment, accountability, and results. Results from the interviews and IRBS aligned with Lencioni's framework and were presented to executive management with the recommendation to survey the broader stakeholder population. The use of Lencioni's framework and the use of a survey to more broadly assess the behavioral landscape was approved.

The survey consisted of 20 questions regarding the five dysfunctions and used a Likert scale with the following response categories: (1) strongly disagree, (2) disagree, (3) neither agree or disagree, (4) agree, and (5) strongly agree. The survey questions and their associated Level 1 risks are displayed in Table 19. The survey was sent to 950 individuals across all levels of the organization (ca. 15% of total stakeholder population), and 665 responses were received (ca. 70% response rate), with all divisions and organizational levels responding in close proportions.

Table 19. Survey questions

Intangible risk	Survey question
Avoidance of accountability	Stakeholders offer unprovoked, constructive feedback to one another.
Lack of commitment	Stakeholders leave meetings confident that everyone is committed to the decisions that were agreed.
Lack of commitment	Stakeholders end discussions with clear and specific resolutions.
Lack of commitment	Stakeholders are aligned around common objectives.
Lack of commitment	The project team is decisive, even when sufficient information is not available.
Lack of commitment	The project team sticks to decisions once made.
Lack of commitment	Stakeholders support team decisions outside the room even if they disagreed inside.
Lack of commitment	Stakeholders respect each other.
Lack of commitment	Stakeholders are clear about direction and priorities.
Fear of conflict	Stakeholders solicit one another's opinions during meetings.
Fear of conflict	When conflict occurs, stakeholders confront and deal with the issue before moving to another subject.
Fear of conflict	During meetings between stakeholders, the most important and difficult issues are discussed.
Fear of conflict	Stakeholders voice their opinions even at the risk of causing disagreement.
Inattention to results	When a meeting fails to achieve collective goals, stakeholders take personal responsibility to improve the team's performance.
Inattention to results	Stakeholders place little importance on titles and status.
Inattention to results	Meetings between stakeholders are productive.
Absence of trust	Stakeholders ask for reciprocal help without hesitation.
Absence of trust	Stakeholders ask others for input regarding their own area of responsibility.
Absence of trust	Stakeholders trust each other.
Absence of trust	Stakeholders actively cooperate outside "official" meetings.

The consolidated survey results (Table 20) validated the concerns raised in the interviews regarding teamwork and behaviors. The survey results were analyzed and categorized, with highest-risk areas having a score below 3.5 (shaded) and high- to medium-risk areas having scores between 3.49 and 3.9 (unshaded). The average scores from the projects and engineering division, operations division, and remaining support divisions (e.g., finance) are shown in Figure 16. The responses (Figure 16) indicated broad agreement regarding the need to focus on the behavior-centric intangible risks. While all three divisions were reasonably aligned in their views, the support functions viewed accountability and commitment as requiring more focus. These results were presented to the OilCo executive management team with the recommendation to further assess response areas with scores below 4 (agree) with an initial focus on the high to medium risks. This recommendation was approved.

Table 20. Survey results

Survey question	Response
Stakeholders offer unprovoked, constructive feedback to one another.	3.39
Stakeholders leave meetings confident that everyone is committed to the decisions that were agreed.	3.50
Stakeholders end discussions with clear and specific resolutions.	3.48
Stakeholders are aligned around common objectives.	3.48
The project team is decisive, even when sufficient information is not available.	3.15
The project team sticks to decisions once made.	3.46
Stakeholders support team decisions outside the room even if they disagreed inside.	3.14
Stakeholders actively cooperate outside “official” meetings.	3.53
Stakeholders respect each other.	3.88
Stakeholders solicit one another’s opinions during meetings.	3.60
When conflict occurs, stakeholders confront and deal with the issue before moving to another subject.	3.40
During meetings between stakeholders, the most important and difficult issues are discussed.	3.76
Stakeholders voice their opinions even at the risk of causing disagreement.	3.61
When a meeting fails to achieve collective goals, stakeholders take personal responsibility to improve the team’s performance.	3.28
Stakeholders place little importance on titles and status.	3.00
Meetings between stakeholders are productive.	3.68
Stakeholders are clear about direction and priorities.	3.55
Stakeholders ask for reciprocal help without hesitation.	3.62
Stakeholders ask others for input regarding their own area of responsibility.	3.41
Stakeholders trust each other.	3.50

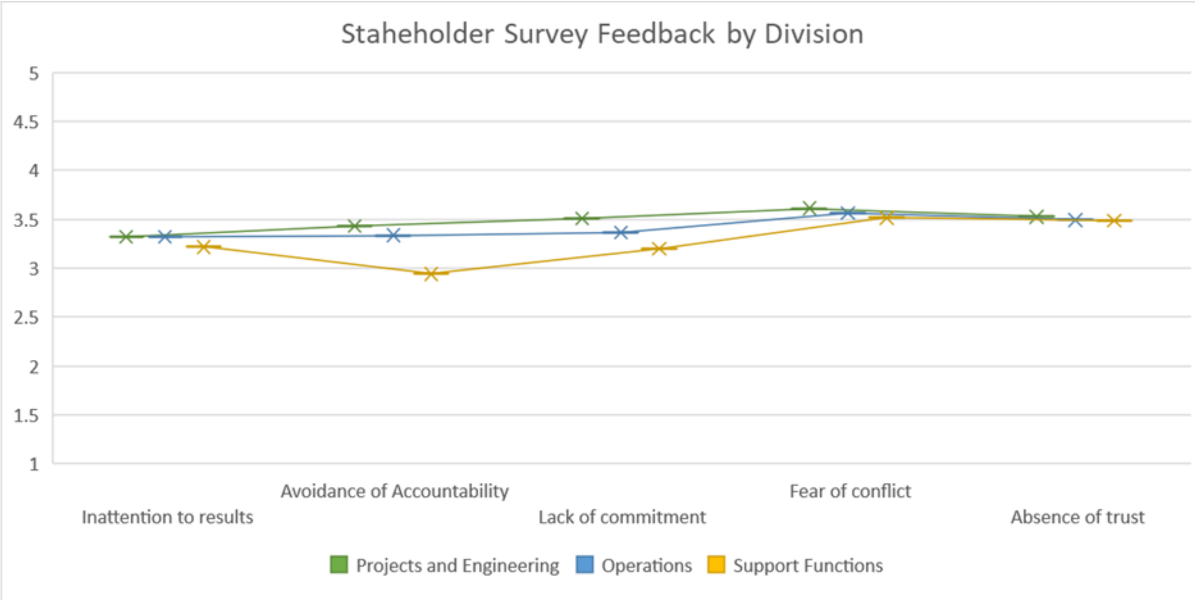


Fig. 16. Survey results comparison by division.

A meeting was held with OilCo SMEs from the stakeholder groups (operations, projects, engineering, and finance) to review and validate the IRBS and metanetwork and to identify the highest-risk causal factors. This meeting was attended by six SMEs with more than 175 years of combined industry experience. The IRBS and metanetwork were agreed on as presented for use in the project team workshops. However, the causal factor checklist was modified to better reflect the project environment. Table 21 shows the agreed-on IRBS and indicators, and Table 22 contains the agreed-on "customized" list of causal factors for the assessment and the agreed-on indicators (e.g., IRF1, RT1, etc.), which were used in the ORA-PRO simulation.

Table 21. Behavior-centric IRBS

Level 0	Level 1	Level 2	Indicator
Intangible risk	Absence of trust	Conceals weakness and mistakes	IRF1
		Hesitates to ask for help or provide constructive feedback	IRF2
		Jumps to conclusions about intentions and aptitudes of others without clarifying	IRF3
		Fails to recognize and tap into others' skills and experiences	IRF4
		Wastes time and energy managing behaviors for effect	IRF5
		Holds grudges	IRF6
		Finds reasons not to engage meaningfully	IRF7
	Fear of conflict	Holds ineffective meetings	IRF8
		Creates environments where back-channel politics and personal attacks thrive	IRF9
		Ignores controversial topics critical to team success	IRF10
		Fails to tap into all the opinions and perspectives of team members	IRF11
		Wastes time and energy with posturing and interpersonal risk management	IRF12
	Lack of commitment	Creates ambiguity among the team about direction and priorities	IRF13
		Misses deadlines and opportunities because of excessive analysis and delay	IRF14
		Breeds lack of confidence and fear of failure	IRF15
		Revisits discussions and decisions again and again	IRF16
		Encourages second-guessing and distancing among team members	IRF17
	Avoidance of accountability	Creates resentment among team members who have different levels of performance	IRF18
		Encourages mediocrity	IRF19
		Misses deadlines and key deliverables	IRF20
		Places undue burden on the leader as the sole source of discipline	IRF21
	Inattention to results	Stagnates / fails to grow	IRF22
		Rarely is proactive	IRF23
		Loses achievement-oriented staff	IRF24
		Encourages individuals to primarily support their group or themselves	IRF25
		Is easily distracted and inwardly focused	IRF26
		Will not bear an extra burden of another group even to benefit OilCo	IRF27

Table 22. OilCo causal factors

Causal factor	Indicator
Lack of clearly defined goals and objectives	RT1
Lack of active management support	RT2
Improperly defined/agreed priorities	RT3
Poorly defined roles and responsibilities	RT4
Inadequate or vague requirements	RT5
Insufficient organizational structure for scope of work (lack of appropriate skills)	RT6
Culture (punitive, insecure)	RT7
Ineffective decision making	RT8
Key stakeholder misalignment	RT9
Contradicting interpretations of internal policies and procedures	RT10
Inappropriate risk tolerance	RT11
Ineffective communication	RT12
Inability to change or accept change	RT13
Meeting key stakeholder expectations	RT14
Inadequate review processes	RT15

Project Workshops to Identify Risk and Factor Prevalence

Ten workshops were organized and facilitated to identify which behavior-centric intangible risks and causal factors were most prevalent in OilCo's projects. Six of these workshops were with project teams from completed projects, three with teams from in-progress projects (portfolio projects), and one with senior management. The combined attendance was 150 OilCo staff (ca. 120 technical and supervisory staff and 30 senior managers), representing more than three millennia of industry experience. The workshop with management was held last so that the results from all the workshops could be compared and the results discussed.

The initial step for the workshops was to identify the behavioral risks experienced by the various groups using the RIM framework. Table 23 is an excerpt from the RIM showing the Level 2 intangible risks from the IRBS associated with absence of trust. Workshop participants were asked to come to a consensus on the presence or absence of trust for each risk. The consolidated input from the participants indicated all of the intangible risks associated with absence of trust to have the potential to occur, while the presence of trust was scant. This was repeated for all Level 2 behavior-centric intangible risks.

Table 23. Excerpt from RIM assessment for intangible risk (presence/absence of trust)

Absence of trust	Yes/no	Presence of trust	Yes/no
Conceals weakness and mistakes	Yes	Admits weakness and mistakes	No
Hesitates to ask for help or provide constructive feedback	Yes	Asks for help and provide constructive feedback	No
Jumps to conclusions about intentions and aptitudes of others without trying to clarify them	Yes	Accepts questions and input about their activities	No
Fails to recognize and tap into others' skills and experiences	Yes	Gives others the benefit of the doubt	No
Wastes time and energy managing their behaviors for effect	Yes	Appreciates and taps into others' skills and experiences	No
Holds grudges	Yes	Focuses time and energy on important issues not politics	No
Finds reasons not to engage meaningfully	Yes	Finds reasons to engage meaningfully	No

Next, using a consensus approach, the workshop participants were asked to identify the causal factors likely to precipitate the intangible risks identified previously. Table 24 contains a sample of the input from the nine project team workshops (with letters indicating the various projects) linking the risk causal factors to the absence-of-trust Level 2 risks. The RIM elucidated the complex nature of behavior adaptation, providing support for Rasmussen's "random movements" conceptualization (Rasmussen 1997).

The consolidated results for the intangible risks and risk causal factors from the project workshops are presented in Figure 17 and Figure 18. In each case, approximately one-third of the measures received more than 50% of the responses.

Table 24. Consolidated RIM for absence-of-trust intangible risk (each letter indicates a project team's feedback)

	IFR1	IFR2	IFR3	IFR4	IFR5	IFR6	IFR7
RT1	g				b, h		b, e, g
RT2			d	b			i
RT3	e	d	d		h		b, d, e
RT4	b, i		h	d, g			b, d, e, f, g
RT5	i			b			c
RT6	c, e						e
RT7	a, b, d, g, h	h	h		b	d	e, d
RT8	e, h	h	h	g	a		
RT9	d, e, g	b, d		d, g	b, h	d	a, c, d, e, f, g
RT10	e						e, g
RT11					d		
RT12	h	h	h	d	d, h		g
RT13	e, g, h	h	h				
RT14							
RT15	e		h				

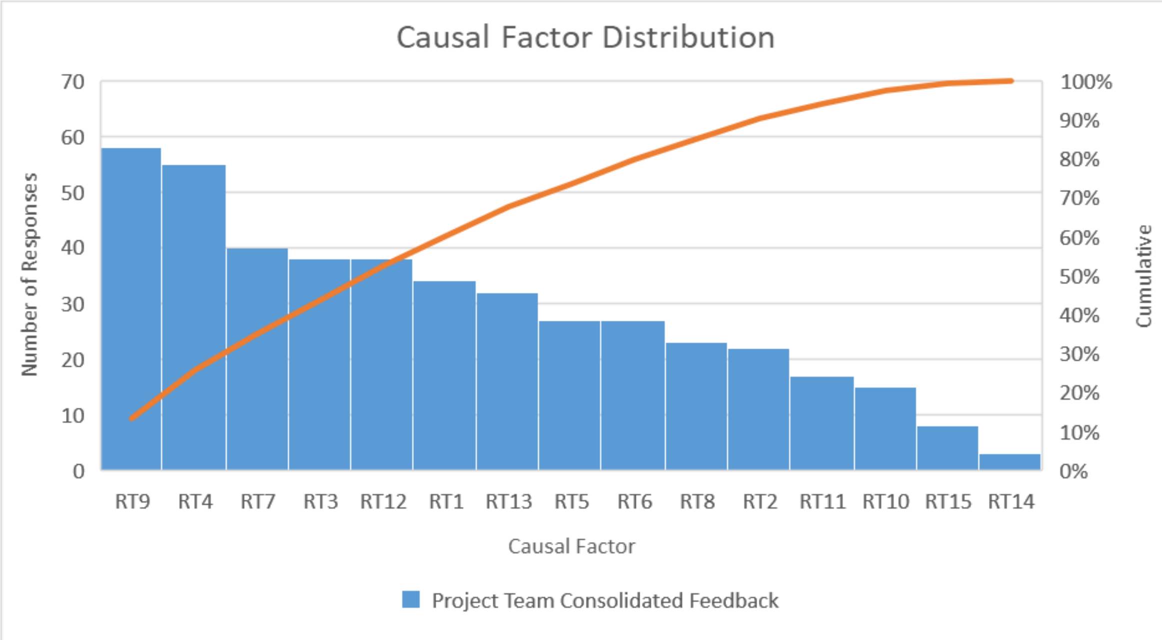


Fig. 17. OilCo risk causal factor responses from project workshops.

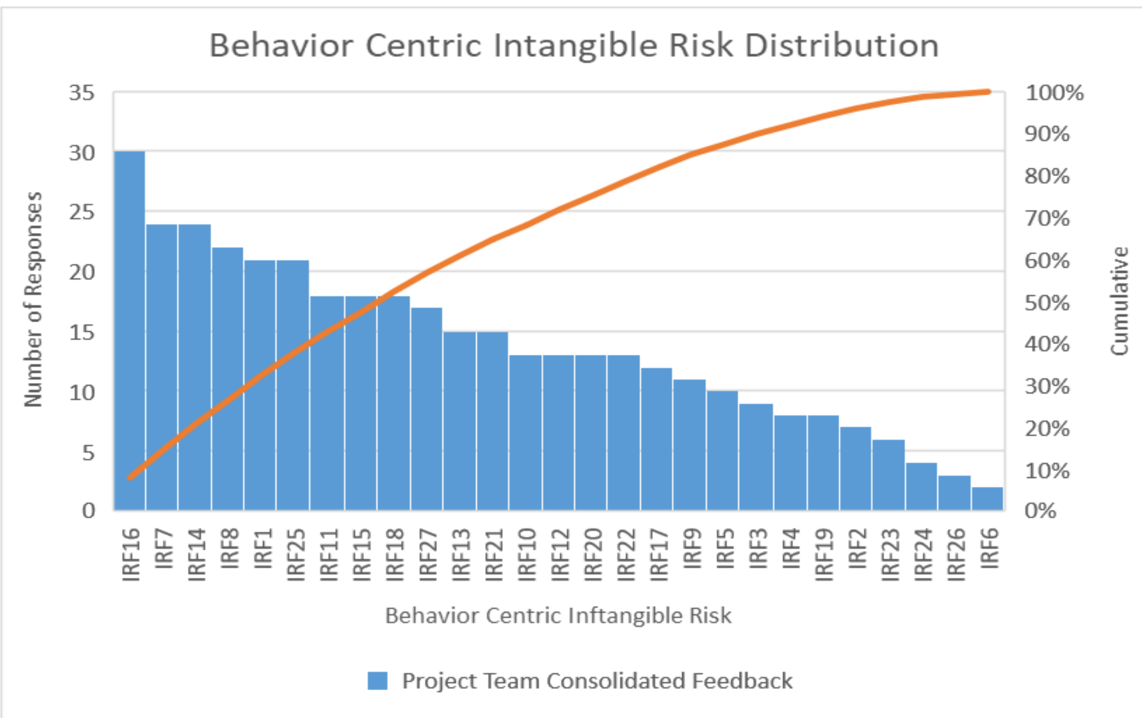


Fig. 18. OilCo behavior-centric intangible risk responses from project workshops.

The final workshop was held with members of senior management from the stakeholder groups to provide a broader perspective. The time available with senior management was constrained because of their other commitments; to accommodate this time constraint, the session was modified. In the management session, instead of the entire group working through the entire set of RIM worksheets (one for each set of Level 2 risks), five groups were formed; each did one of the RIM worksheets and then reported back to all the attendees. In the management session, 12 intangible risks were identified; these were compared to the top 12 (representing ca. 65% of the responses) from the project team sessions. The behavior-centric intangible risk factor comparison can be seen in Table 25. The comparison of the Level 2 behavior-centric intangible risks in Table 25 indicates alignment on 5 of the top 12 risks; however, using an assessment of the Level 1 risks (Figure 19), the perspectives were more consistent.

Table 25. Behavior-centric intangible risk comparison

Project team feedback	Management team feedback
IRF16_Revisits discussions and decisions again and again	IRF3_Jumps to conclusions about intentions and aptitudes of others without clarification
IRF7_Finds reasons not to engage meaningfully	IRF9_Creates environments where back-channel politics and personal attacks thrive
IRF14_Misses deadlines and opportunities because of excessive analysis and delay	IRF10_Ignores controversial topics that are critical to team success
IRF8_Holds ineffective meetings	IRF13_Creates ambiguity among the team about direction and priorities
IRF1_Conceals weakness and mistakes	IRF14_Misses deadlines and opportunities because of excessive analysis and delay
IRF25_Encourages individuals to support their group or themselves primarily	IRF16_Revisits discussions and decisions again and again
IRF11_Fails to tap into all the opinions and perspectives of team members	IRF17_Encourages second-guessing and distancing among team members
IRF15_Breeds lack of confidence and fear of failure	IRF20_Misses deadlines and key deliverables
IRF18_Creates resentment among team members who have different levels of performance	IRF21_Places undue burden on the leader as the sole source of discipline
IRF27_Will not bear an extra burden of another group even if OilCo benefits overall	IRF23_Rarely is proactive
IRF13_Creates ambiguity among the team about direction and priorities	IRF24_Loses achievement-oriented staff
IRF21_Places undue burden on the leader as the sole source of discipline	IRF25_Encourages individuals to support their group or themselves primarily

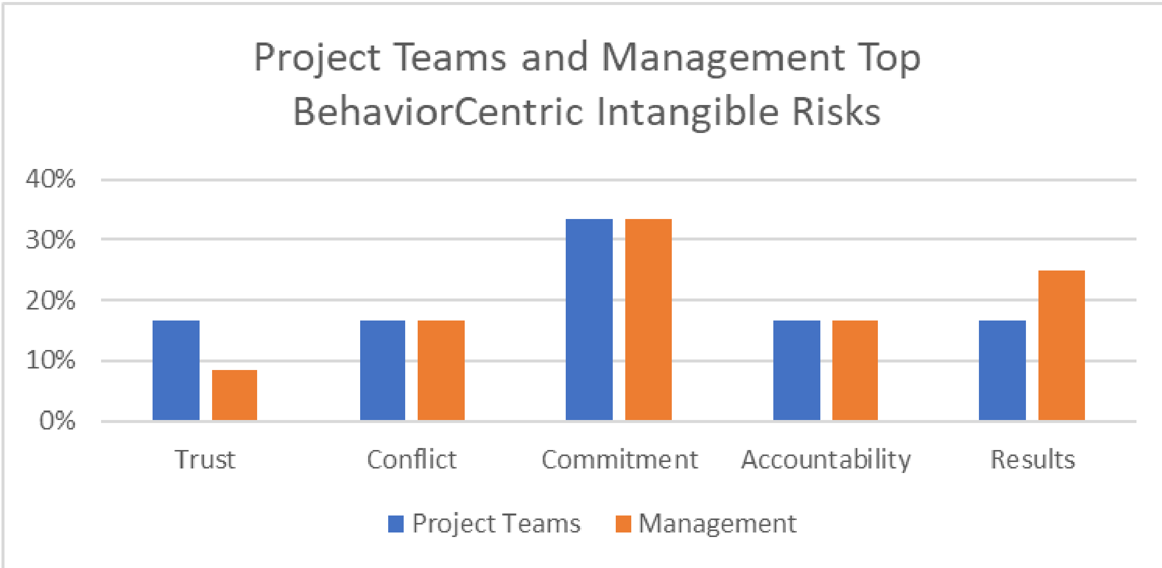


Fig. 19. Behavior-centric intangible risk comparison between project teams and management.

The behavior-centric intangible risks appeared to support Rasmussen's perspective of differing gradients. Compared to project team members, management viewed the implications to results higher and to trust lower, while the cultural gradient may have shaped the views of conflict, commitment, and accountability. Comparison of causal factors (Table 26) indicated a shared understanding of the factors causing the behavioral responses, although contrariwise in order of priority.

Table 26. Casual factor feedback comparison

Project team feedback	Management team feedback
RT9_Key stakeholder misalignment	RT7_Culture (punitive, insecure)
RT4_Poorly defined roles and responsibilities	RT12_Ineffective communication
RT7_Culture (punitive, insecure)	RT3_Improperly defined/agreed priorities
RT3_Improperly defined/agreed priorities	RT5_Inadequate or vague requirements
RT12_Ineffective communication	RT4_Poorly defined roles and responsibilities
RT1_Lack of clearly defined goals and objectives	RT9_Key stakeholder misalignment
RT13_Inability to change or accept change	RT1_Lack of clearly defined goals and objectives
RT5_Inadequate or vague requirements	RT10_Contradicting interpretations of internal policies and procedures
RT6_Insufficient organizational structure for scope of work	RT13_Inability to change or accept change
RT8_Ineffective decision making	RT2_Lack of active management support
RT2_Lack of active management support	RT6_Insufficient organizational structure for scope of work
RT11_Inappropriate risk tolerance	RT11_Inappropriate risk tolerance
RT10_Contradicting interpretations of internal policies and procedures	RT8_Ineffective decision making
RT15_Inadequate review processes	RT14_Meeting key stakeholder expectations
RT14_Meeting key stakeholder expectations	RT15_Inadequate review processes

The IRBS, causal factor checklist, RIM, and data collection workshops were well received by all project teams, especially management. All participants acknowledged the value of having a structured forum to discuss behavior-centric risks—providing an empirically based validation of this portion of IRAMP. Interestingly, the management workshop participants were not surprised that the results were so closely aligned and felt that going through the exercise of filling in the RIM was as valuable as the results. This outcome underscores the utility of Cobb's paradox (“We know why projects fail; we know how to prevent their failure – so why do they still fail?”), as well as the potential value of utilizing IRAMP on a broader scale within OilCo.

Assessment of Project Portfolio Stages

Three active projects (P1, P2, P3) were selected to create the portfolio and to assess the intangible risks and causal factors by stage:

- *P1*: $250 million complex brownfield process plant upgrade in the stage of pre–front end engineering design (FEED)
- *P2*: $800 million greenfield pipeline and storage infrastructure project in the FEED stage
- *P3*: $150 million offshore production facility installation in the execution stage

Using this portfolio to assess behavior-centric intangible risks and their causal factors may be subject to criticism. Recognizing that behaviors are the product of sociotechnical interactions in a particular environment (Rasmussen 1997), three different project settings with different stakeholders do not provide a consistent picture of how the behaviors and causal factors systematically emerge. This is a reasonable challenge; however, given the time frame for the organizational assessment (one year), it was not possible to follow individual projects for their entire life cycles. This approach is not without some level of precedent. Thamhaim and Wilemon surveyed 100 project managers regarding conflict and conflict resolution during the project development cycle without controlling for specific project feedback in their study addressing conflict during the project development cycle (Thamhaim and Wilemon 1975). Also, in the context of OilCo, the microdynamics faced by each project were different, but the macro-organizational influences could be viewed to provide a level of consistency (Ancona et al. 1999). The top behavior-centric risks and causal factors from the portfolio by stage were compared to those from the ex-post projects to check the viscidity of the framework.

Shown in Table 27, the behavior-centric intangible risks of P1 in the pre-FEED stage appeared to coalesce around two key themes: teamwork and effective decision making. Progressing to the FEED stage (P2), additional behavioral issues arose around politics (creates environments where back-channel politics and personal attacks thrive, ignores controversial topics critical to team success) and resource utilization (hesitates to ask for help or provide constructive feedback, stagnates / fails to grow, rarely is proactive, encourages mediocrity). In addition to all of the behavior-centric factors from the prior stages continuing to manifest, others emerged during the execution stage (P3): misjudging intentions of others, holding grudges, ambiguity about direction and priorities, lack of confidence and fear of failure, resentment among team members, and inward focus.

Behavior-centric risk factors occurring in the various project stages of the portfolio were compared to the information from the previous ex-post project workshops (Figure 20). The teams currently executing the projects in the portfolio had different risk rankings than the teams from the completed projects. These results are explored in more detail in the MNA section of this chapter.

Table 27. Behavior-centric intangible risks by project stage

Intangible risk	Pre-FEED	FEED	Execution	Indicator
Conceals weakness and mistakes		x	x	IRF1
Hesitates to ask for help or provide constructive feedback		x	x	IRF2
Jumps to conclusions about intentions and aptitudes of others without clarifying them			x	IRF3
Fails to recognize and tap into others' skills and experiences		x	x	IRF4
Wastes time and energy managing behaviors for effect		x	x	IRF5
Holds grudges			x	IRF6
Finds reasons not to engage meaningfully	x	x	x	IRF7
Holds ineffective meetings	x	x	x	IRF8
Creates environments where back-channel politics and personal attacks thrive		x	x	IRF9
Ignores controversial topics critical to team success		x	x	IRF10
Fails to tap into all the opinions and perspectives of team members		x	x	IRF11
Wastes time and energy with posturing and interpersonal risk management	x	x	x	IRF12
Creates ambiguity among the team about direction and priorities			x	IRF13
Misses deadlines and opportunities because of excessive analysis and delay	x	x	x	IRF14
Breeds lack of confidence and fear of failure			x	IRF15
Revisits discussions and decisions again and again	x	x	x	IRF16
Encourages second-guessing and distancing among team members	x	x	x	IRF17
Creates resentment among team members who have different levels of performance			x	IRF18
Encourages mediocrity		x	x	IRF19
Misses deadlines and key deliverables	x	x	x	IRF20
Places undue burden on the leader as the sole source of discipline		x	x	IRF21
Stagnates / fails to grow		x	x	IRF22
Rarely is proactive		x	x	IRF23
Loses achievement-oriented staff				IRF24
Encourages individuals to primarily support their group or themselves	x	x	x	IRF25
Is easily distracted and inwardly focused			x	IRF26
Will not bear an extra burden of another group even to benefit OilCo	x	x	x	IRF27

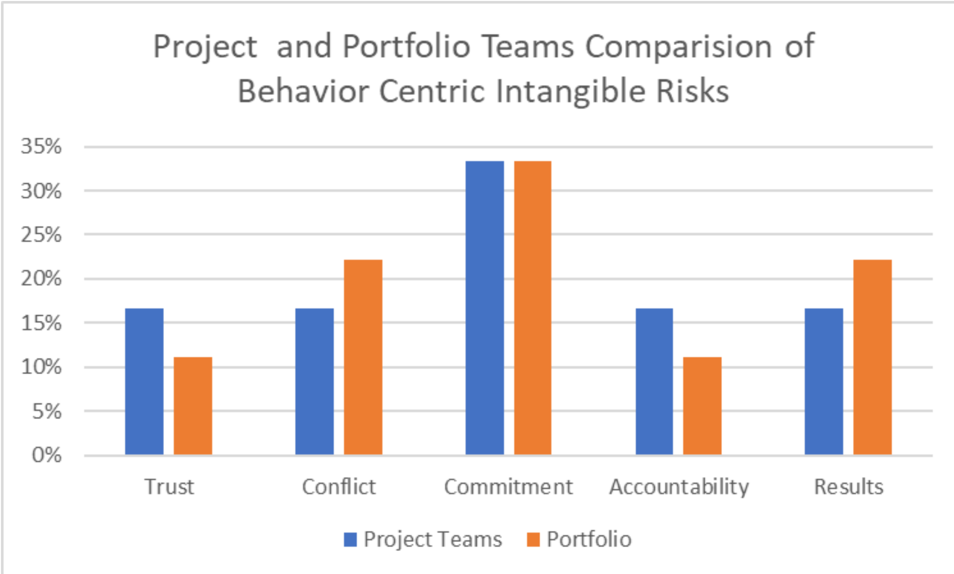


Fig. 20. Project and project portfolio behavior-centric intangible risk team feedback comparison between currently ongoing portfolio projects and completed projects.

The causal factors for the portfolio are shown in Table 28. Like the previous behavior-centric intangible risk comparison, the portfolio causal factors present in all stages were compared to the ex-post projects (Table 29). This comparison showed four of six causal factors matching with the portfolio teams, with lack of active management support and vague requirements more prevalent than the ex-post teams. This difference may have been caused by the tenures of the teams (two of the three portfolio project teams had been with OilCo fewer than three months). This outcome provides additional support for the assertion that overall macro-organizational factors can be at play while the particulars of the project context can vary.

Table 28. Causal factors by project stage

Causal factor	Pre-FEED	FEED	Execution	Indicator
Lack of clearly defined goals and objectives	x	x	x	RT1
Lack of active management support	x	x	x	RT2
Improperly defined/agreed priorities		x	x	RT3
Poorly defined roles and responsibilities	x	x	x	RT4
Inadequate or vague requirements	x	x	x	RT5
Insufficient organizational structure for scope of work (lack of appropriate skill)			x	RT6
Culture (punitive, insecure)	x	x	x	RT7
Ineffective decision making	x			RT8
Key stakeholder misalignment	x	x	x	RT9
Contradicting interpretations of internal policies and procedures			x	RT10
Inappropriate risk tolerance		x	x	RT11
Ineffective communication		x	x	RT12
Inability to change or accept change			x	RT13
Meeting key stakeholder expectations	x			RT14
Inadequate review processes	x	x		RT15

Table 29. Causal factor comparison between currently ongoing portfolio projects and completed projects

Project teams	Portfolio
RT9_Key stakeholder misalignment	RT7_Culture (punitive, insecure)
RT4_Poorly defined roles and responsibilities	RT2_Lack of active management support
RT7_Culture (punitive, insecure)	RT1_Lack of clearly defined goals and objectives
RT3_Improperly defined/agreed priorities	RT5_Inadequate or vague requirements
RT12_Ineffective communication	RT4_Poorly defined roles and responsibilities
RT1_Lack of clearly defined goals and objectives	RT9_Key stakeholder misalignment

The behavioral concerns raised in the initial interviews and the workshops highlighted the following opportunity areas:

- Align priorities and objectives
- Increase communication effectiveness and decision making
- Improve interdivision interactions, engagement, and teamwork
- Clarify roles, responsibility, and authority
- Challenge the culture

These opportunity areas are consistent with the prerequisites for effective project execution found in the literature. Ensuring that proper resources are made available for effective front-end planning and providing clarity around roles and responsibilities are critical to project success (Muiño and Akselrad 2009). Project requirements, objectives, and scope must be agreed on and "frozen" prior to entering the FEED stage of project development. This stage also requires that roles, responsibilities, communication protocol, and stakeholder involvement be clearly defined, agreed on, and supported by senior management (Kerzner 2009; Salapatas 2000).

The evolution of the behavior-centric intangible risks in the portfolio highlights the importance of a structured approach for early identification of causal factors and their consequences. Failing to address behavior-centric issues and their causal factors early in the project development cycle can lead to a compounding effect, resulting in what Roth and Senge described as “wicked messes” (Roth and Senge 1996); said proverbially, what starts wrong usually ends wrong. Having established the behavior-centric intangible risks and causal factors and the interactions between them, the project stakeholders (agents) and tasks were identified and analyzed to identify opportunities to enhance project delivery success.

Metanetwork Development

The next step was to create the metanetwork portion of IRAMP. The information from the risk workshop, existing responsibility matrices, organization charts, and the WBS were used to create the networks comprising the metanetwork for each of the portfolio projects. Adjacency matrices were developed for each of the identified networks and were prepopulated prior to the metanetwork SME review and project team workshops. The following modifications were made to the metanetwork presented in Table 9 for use in the OilCo context:

- All behavioral risks influence each other to some extent; it’s assumed that all influence each other the same. Note: the network of behavior-centric intangible risk factor × behavior-centric intangible risk factor is not included in the MNA.
- Agents are assumed to influence the causal factors, and it is the causal factors that influence the behaviors; therefore, the network of agent × behavior-centric intangible risk factor is excluded from the MNA.
- Causal factors have an indirect impact on tasks because the behaviors that directly impact tasks are influenced by causal factors; therefore, the network of causal factor × task is not

included in the MNA. Indicators are the abbreviations used in in the metanetwork simulation.

The resultant metanetwork for the OilCo assessment is shown in Table 30.

Templates of the adjacency matrices, along with an acronymic listing for the modeling, were developed to elucidate the metanetwork approach to the SMEs and project teams for their feedback. A simplified version of the communication network (agent × agent) is provided in Table 31. Once the feedback from the workshops was incorporated, the adjacency matrices were uploaded into ORA-PRO to simulate the portfolio and identify opportunities to improve project performance.

Table 30. OilCo metanetwork

	Agent	Causal factor	Behavior-centric intangible risk factor	Task
Agent	Communication network: who interacts with whom	Activation network: who "lights the fuse"	N/A: interaction between actor and causal factor	Assignment network: who is involved (input/review) in which task
Causal factor		Dependence: factor-to-factor interaction	Influence network: factor influence on risk	N/A: some tasks are dependent on other tasks, but the intangible risks influence the agent performing the task
Behavior-centric intangible risk factor			N/A: all risks are assumed to influence each other	Contagion network: how the risk manifests
Task				Interaction network: task interactions with other tasks

Table 31. Adjacency matrix template (agent × agent)

	Agent 1	Agent 2	Agent 3	Agent 4	….	….	Agent x
Agent 1		1					
Agent 2				1			
Agent 3	1						
Agent 4			1				
:							
:							
Agent x							

In organizations, it is possible for an individual's or a group's performance to be hindered by some gap or barrier. This may be a physical gap, such as distance between work locations, or a procedural barrier to effective interaction, such as misaligned goals and objectives. However, cultural gaps between groups (e.g., finance, operations, and project management) or barriers to trust due to individuals being unaccustomed to working together are by their nature abstruse (Long et al. 2013). The organizational construct for OilCo is functionally based (e.g., operations, engineering, project management, etc.), with staff being assigned to projects by functional managers based on expertise and availability. Formal memoranda from one department manager to another are the common form of communication. The key stakeholder divisions involved in the development and delivery of projects and the requisite reporting relationships are depicted in Figure 21. Table 32 shows descriptive information for the OilCo organigram.

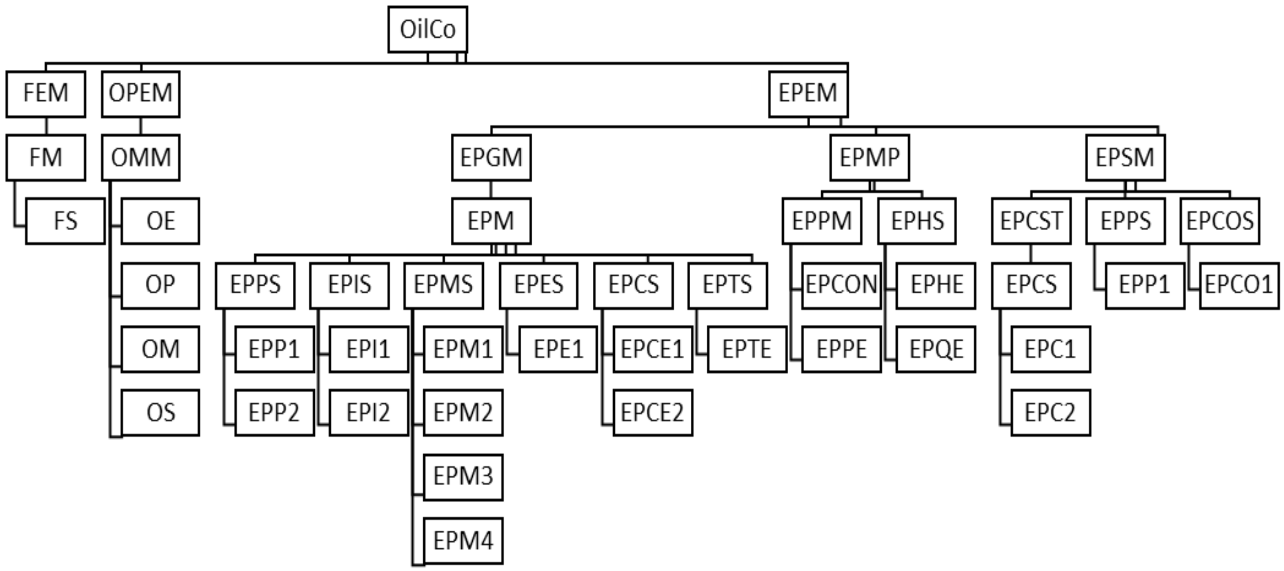


Fig. 21. OilCo organizational representation.

Table 32. OilCo organization titles and indicators

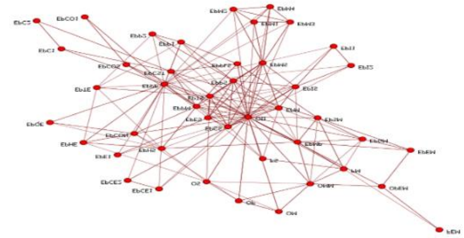
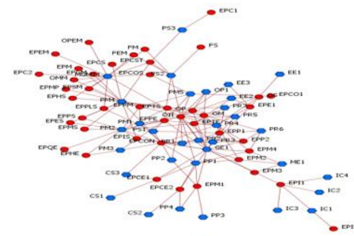
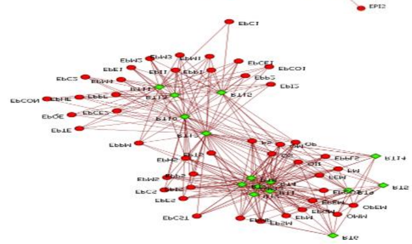
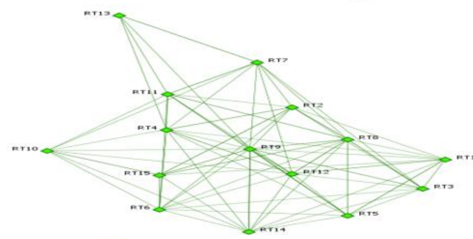
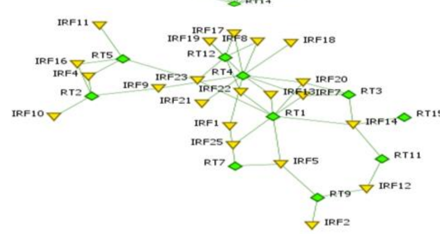
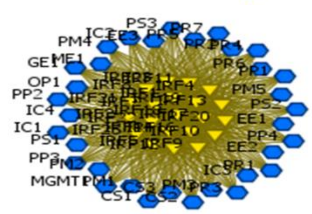
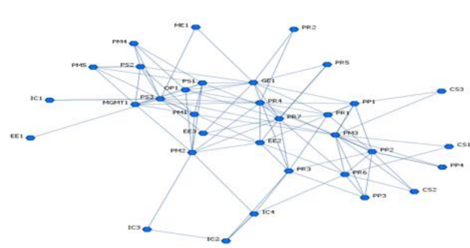
Title	Indicator	Title	Indicator	Title	Indicator
Vice President Operations	OPEM	Supervisor Instrument and Control	EPIS	Manager Project Management	EPMP
Manager Operations	OMM	Instrument and Control Engineer	EPI1	Project Manager	EPPM
Operations Production	OP	Telecom Engineer	EPI2	Project Engineer	EPPE
Operations Maintenance	OM	Supervisor Mechanical Engineering	EPMS	Construction Supervisor	EPCON
Operations Engineering	OE	Piping Engineer	EPM1	Supervisor HSE, Risk and Quality	EPHS
Operations Safety	OS	Static Equipment Engineer	EPM2	HSE Engineer	EPHE
Vice President Finance	FEM	Materials and Corrosion Engineer	EPM3	QA/QC Engineer	EPQE
Manager Finance	FM	Rotating Equipment Engineer	EPM4	Manager Project Services	EPSM
Supervisor Finance	FS	Supervisor Electrical Engineering	EPES	Supervisor Cost Engineering	EPCST
Vice President Engineering and Project Management	EPEM	Electrical Engineer	EPE1	Cost Engineer	EPC1
General Manager Engineering	EPGM	Supervisor Civil Engineering	EPCS	Economics Analyst	EPC2
Assistant Manager Engineering	EPM	Civil Engineer	EPC1	Supervisor Planning Engineering	EPPS
Supervisor Process Engineering	EPPS	Structural Engineer	EPC2	Planning Engineer	EPP1
Process Engineer	EPP1	Supervisor Technical HSE	EPTS	Supervisor Contract	EPCOS
Process Utility Engineer	EPP2	Technical HSE Engineer	EPTE	Contract Engineer	EPCO1

OilCo policy has limited authority for decisions and setting direction to the vice presidents, with limited delegation to managers. The authority delegated to assistant managers and supervisors has been for assigning team resources to projects, while the balance of the organization has had no formal authority. However, delegation of responsibility and accountability for delivery without authority has been a common practice. In the context of OilCo's culture, the ability to influence stakeholders from other departments has been challenging at the vice president and manager levels and has been virtually nonexistent for the assistant manager, supervisor, and individual performer levels. These factors created a situation where the project team, supervisors, and staff members found themselves being held accountable without the ability to influence other stakeholders. Research by the Executive Leadership Group, a leadership and organizational transformation consultancy, has found responsibility without authority and unclear project goals to be leading causes of project failure (Peck and Casey 2011).

The formal organizational structure and reporting relationships indicate a static and deterministic perspective of organizational interaction. However, the interactions between stakeholders and the subsequent implications to behaviors and task completion have been dynamic and stochastic (Cook and Rasmussen 2005). Utilizing MNA provides a perspective of the complexity of the interactions among stakeholders in the project context.

The metanetwork was simulated using ORA-PRO software. The origin of ORA-PRO was the Dynamic Networks project of Carnegie Mellon's CASOS. The model is commercially available through Netanomics, an entity of Carley Technologies (Carley et al. 2013). The visualization capability of ORA-PRO can be seen in Table 33 (individual networks) and Figure 22 (metanetwork). These visualizations highlight the complexity of multiple network interactions and why tools designed for monolithic systems are at an analytical disadvantage.

Table 33. Individual networks making up the metanetwork

Network	Image
Communication network (agent × agent) Identifies the interactions between stakeholders. Developed from the responsibility matrix and the organization chart.	
Assignment network (agent × task) Identifies which agents are involved in specific tasks and highlights the workload distribution of the stakeholders. Developed from the responsibility matrix.	
Activation network (agent × causal factor) Identifies which stakeholders influence which of the causal factors. Developed in a project stakeholder workshop.	
Dependence network (causal factor × causal factor) Identifies which causal factors interact with each other either to initiate the causal factor or to magnify it.	
Influence network (causal factor × behavior-centric intangible risk factor) Identifies which causal factors provoke which behavior-centric intangible risk factors.	
Contagion network (behavior-centric intangible risk factor × task) Identifies which intangible risk factors impact the delivery of which tasks.	
Interaction network (task × task) Shows which tasks have a direct influence on other tasks. Developed from the WBS.	

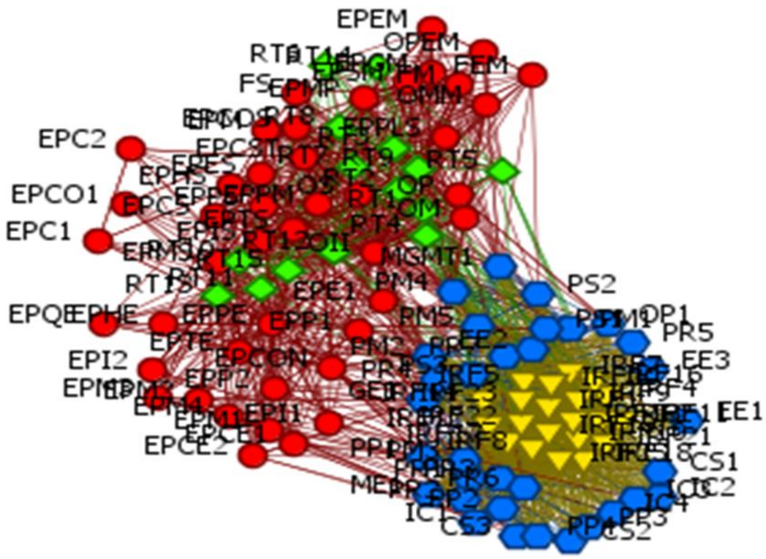


Fig. 22. Metanetwork example from the FEED stage with ca. 120 nodes and 1,600 links.

Metanetwork Analysis

OilCo's performance gap (Figure 15) is in the context of a portfolio of projects. MNA utilized the aforementioned portfolio of P1, P2, and P3 as the sample set for the simulation. These projects were considered a reasonable representation of the overall portfolio for the following reasons:

- They represent the three main sectors of OilCo's operated assets: upstream production, midstream product transportation and storage, and downstream refining.
- They contain both onshore and offshore developments.
- They hold a broad cross-section of stakeholders and multiple project teams.
- They represent the overall portfolio's technical complexity and investment range.
- They represent the phases of the project development cycle.

The initial ORA-PRO simulation integrated the metanetworks for each constituent project (P1, P2, P3) and generated network analysis measures at the portfolio level in terms of the existing organizational workflows. Using this information as a baseline, an analytical framework was developed to validate the simulation results and to compare them to the measures generated for potential organizational modifications. This comparison provided a quantitative basis for organizational recommendations to improve OilCo's project portfolio performance.

The analytical framework (Figure 23) was composed of four steps: validation, identification, evaluation, and recommendation (VIER). The validation portion made two comparisions using the the behavior-centric intangible risks and causal factors. The behavior-centric behavioral risks from ORA-PRO portfolio simulation output were first compared to the workshop feedback from the portfolio teams and then to the ex-post project workshop results. This comparison provided a level of assurance of the model being reasonably aligned with the empirical data. Assessment of the network analysis measures (Table 34) for the existing organization from the simulation took place in the identification step. In this portion of the analytical framework, the network analysis measures (betweenness, eigenvector, etc.) were used to identify the nodes (agents, causal factors, and behavior-centric risk factors) of highest potential organizational influence. This information became the baseline for assessing options for organizational modifications and aligned with the opportunity areas (clarify roles, responsibilities, and authorities; increase communication effectiveness and decision making; align priorities and objectives; impact teamwork; challenge the culture). In the evaluation phase, organizational modification options were simulated, yielding network analysis measures that were compared to the baseline values. The final step was the development of recommendations for organizational modifications to enhance project delivery based on the quantative measures developed in the evaluation phase. The VIER steps are detailed in the following sections.

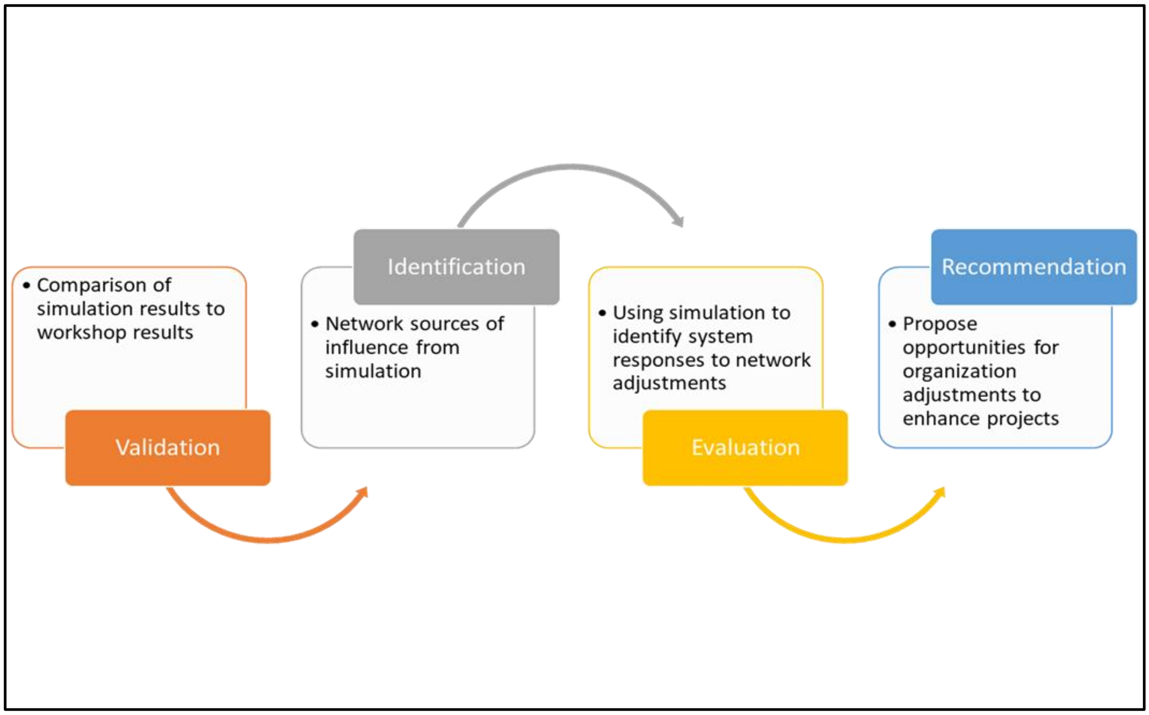


Fig. 23. Analytical framework for MNA to identify opportunities for project delivery enhancement (VIER).

Table 34. Importance of network analysis measures

Measure	Importance
Total degree	This measure is important in identifying the providers of information or intensity of involvement regarding the "pulse" of the network.
Betweenness	This measure is important to identify the actors who are important for effective information flow and can become effective "brokers."
Potential boundary spanner	This measure is important to identify agents who are in key structural positions capable of spanning across organizational boundaries (silos, disciplines, etc.).
Eigenvector	This measure is important to identify the nodes that have the potential to underpin a network cascade. This can be effective in communication or propagation of risk.
Out degree	This measure is important to identify nodes with the largest influence on other nodes in the network.
In degree	This measure is important to identify nodes being influenced by other nodes in the network.
Cognitive demand	This measure is used to identify the workload for each agent. This can help identify key contributors or those who could become bottlenecks due to excessive workload.

Validation

The simulation results were compared with feedback regarding behavior-centric intangible risks and causal factors to provide assurance regarding the utility of the ORA-PRO model. Simulation provides an opportunity to compare consensus feedback given in a workshop with impassive model results to expose areas of potential bias or blind spots, such as revealing a project team's "irrational exuberance" with regard to meeting stretch targets or unveiling cultural dysfunction such as conflict being viewed as a normal part of the organizational modus vivendi. Simulation can provide a level of assurance regarding the robustness of the potential solution.

A comparison of simulation results to the feedback from the workshops with the ex-post project teams and the portfolio project teams for behavior-centric intangible risks is shown in Figure 24. The simulation and project feedback were consistent for conflict, commitment, and results, but had a material variance for trust and accountability. While the ex-post project teams expressed trust as more of an issue than the portfolio project teams, both were understated when compared to the simulation results. While calculus of the model accounts for implications of each of the causal factor interactions, this can highlight agents' discomfort with discussing something as amorphous as trust. Conversely, the project teams reported believing accountability to be a low risk-factor, but the simulation results indicated this not being an issue. These differences provided a basis for the project team members to further explore their perceptions of the risk and causal factor interactions.

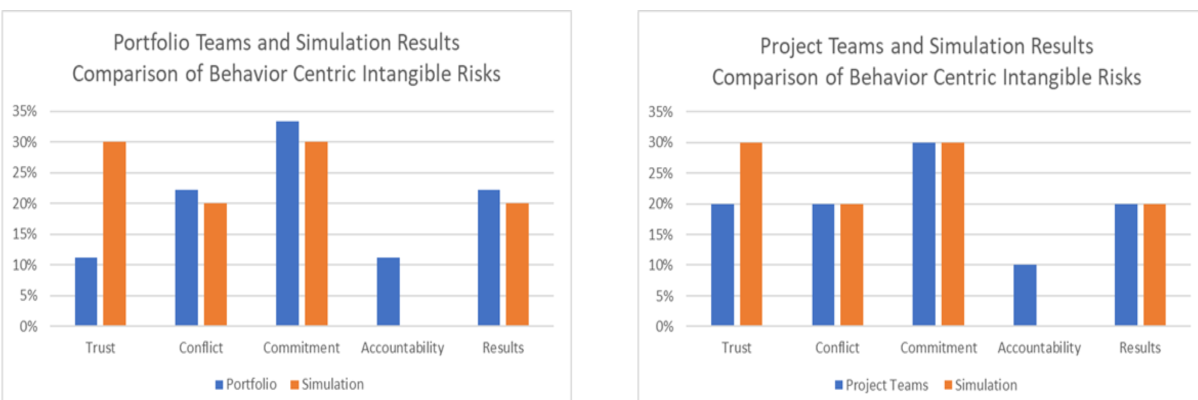


Fig. 24. Comparison of the metanetwork simulation results and feedback from workshops with project teams from completed projects (e.g., ex-post) and portfolio project teams.

The simulation results were shown to be more consistent with the initial interview feedback and to be supported by the literature. Based on an assessment of 112 independent studies comprising more than 7,700 teams, De Jong et al. (2016) demonstrated the existence of a direct relationship between trust within a team and positive performance. Trust is most critical in teams where agents rely on input and resources of other groups, where agents have specific skills, and where different levels of authority exist for decision making and how teams are organized. The portfolio teams were relying on input from others with specific skills, and decision-making authority was unevenly distributed, indicating that trust should be viewed as critical. This disparity was discussed with the portfolio teams, providing them with the opportunity to reassess their position to ensure that no blind spot existed regarding their perspective. The model's general alignment with the ex-post project feedback and the highlight on trust provide assurance regarding the model's veracity.

A similar comparison was made regarding the level of influence for each risk causal factor (Table 35). The alignment was reasonable, with most of the factors being within two steps of each other in the sequence; however, like the behavior-centric intangible risk comparison, those with a larger gap (RT1, RT2, and RT5) provided a basis to explore for potential bias or misinterpretation of the context.

Table 35. Ranking of causal factor simulation vs. workshop feedback

Causal factor	Workshop	Simulation
RT9	1	1
RT4	2	2
RT7	3	5
RT3	4	6
RT12	5	7
RT1	6	3
RT13	7	9
RT5	8	4
RT6	9	11
RT8	10	12
RT2	11	8
RT11	12	10
RT10	13	14
RT15	14	13
RT14	15	15

Identification

In this step, individual network analysis metrics from the existing organization were used to identify the agents who, by virtue of their structural position in the metanetwork, were best placed to inform and influence the opportunity areas. The agents were ranked by their scores for each of the network measures and then grouped by organizational level. The network analysis measures provided a quantitative assessment of the key agents in the organization. Each of the opportunity areas was assessed using applicable network analysis metrics. The use of these network measures addresses the current knowledge gap regarding the ability to quantify behavior-centric intangible risk using an analytical model with appropriate SNA measures. Also, this stage of the analytical framework addressed the research question: Can an analytical tool kit be developed to assess sociotechnical complex networks, along with the network analysis measures of centrality, that can be used to identify organizational or procedural modifications to enhance project delivery performance? Quantitatively assessing each of the aforementioned opportunity areas using established SNA measures of centrality can enhance project delivery in OilCo.

Clarify Roles, Responsibilities, and Authorities

OilCo's responsibility was being delegated without providing the requisite authority. OilCo policy for all decision making for potential financial implications exceeding $50,000 was held at the vice president level, with decisions accountable for less than $50,000 having been delegated to senior managers. However, the responsibility for ensuring that project objectives were met had been fully delegated to the manager and supervisor levels, which led to a lack of clarity of roles and responsibilities within various groups. The only formal authority had by the managers and supervisors was the ability to assign personnel, but at the same time they were expected to ensure that project objectives were met. This has been referred to as the "no-authority gauntlet" (NAG) and has negative implications for project leaders in terms of effective project delivery and influence within the organization (Peck and Casey 2011). Cognitive demand measures the total amount of effort expended by each individual or agent to perform the tasks in their remit. It is a complex measure accounting for the staff, resources, agent-managed tasks, and communication needed to engage (Carley et al. 2013). In this research, cognitive demand was used as a measure of responsibility. In OilCo, the agents with the highest cognitive demand (Table 36) did not have formal authority.

Table 36. Agents and organization levels with the highest values of cognitive demand with authority level

Agent	Cognitive demand	Organization level	Decision authority
OE	0.253	Manager	No
EPPE	0.179	Staff	No
EPPM	0.165	Manager	No
EPMS	0.161	Supervisor	No
OM	0.152	Manager	No
EPPS	0.143	Supervisor	No
EPTS	0.135	Supervisor	No
EPM	0.13	Manager	No
EPCS	0.126	Supervisor	No
EPIS	0.126	Supervisor	No

The issue of responsibility without authority has been widely discussed (a Google search of “no-authority gauntlet” returns almost 3.5 million results); however, there is not a method present in the literature to quantify NAG. In this research, testing for the presence of NAG was defined as cognitive demand by organizational authority level (e.g., executive level, senior manager level, manager level, supervisory level), where cognitive demand is the effort expended by an agent to accomplish their tasks related to project activities. In OilCo, the average cognitive demand score for the manager and supervisory level (0.13) was almost twice that of the executive and senior manager levels. Figure 25 shows 65% of the effort for task accomplishment being expended by the supervisory and management levels, who had no formal authority beyond staff assignments. This can also create a conundrum with regard to roles and responsibilities if stakeholder departments have differing views of project requirements and approaches or differing political objectives. In this type of environment, dysfunctional behaviors can emerge (Beringer et al. 2013; De Jong et al. 2016; Lencioni 2007). Based on feedback from the project team workshops, the supervisory and manager levels had been reluctant to raise issues over concern of being viewed as not doing their jobs or attempting to influence stakeholders from other groups. However, this reluctance creates delays in solving issues or finalizing decisions and ultimately impacts project schedules. The use of cognitive demand provides a quantitative basis to assess an organization for the presence of NAG and to identify options to mitigate its effects on project objectives.

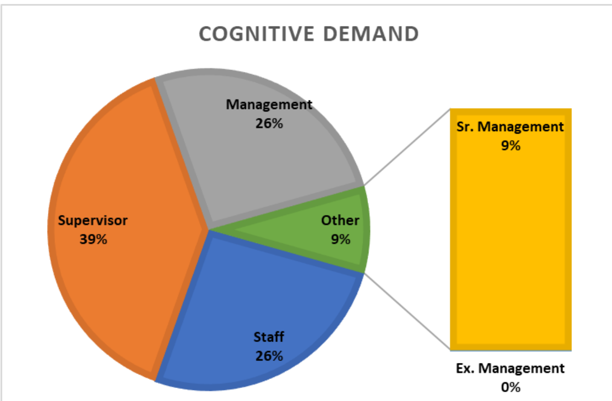


Fig. 25. Cognitive demand by organization level.

Increase Communication Effectiveness and Decision Making

Feedback from the workshops with management and the project teams indicated communication being an influential causal factor. The formality of information flow within OilCo was having implications on effectiveness and efficiency due to the practice of communication between senior managers. The network analysis measure of betweenness is a measure of an agent's level of connectivity with other agents and provides an indication of how information flows within the organization. Table 37 shows the agents with the highest values of betweenness. From an organizational perspective, these results indicate the key roles (e.g., project engineer, key supervisors and managers) able to be leveraged for enhancing communication, as well as those representing a key communication risk between the operations and project divisions. The operations organization relied on a single role without decision-making authority for communication (OE on Table 37), a role also having the highest cognitive load, exposing a potential opportunity for enhancing information flow.

Table 37. Agents and organization levels with the highest values of betweenness with authority level

Agent	Betweenness	Organization level	Decision authority
EPPE	0.336	Staff	No
EPMS	0.256	Supervisor	No
EPPS	0.233	Supervisor	No
EPPM	0.221	Manager	No
EPMP	0.203	Senior manager	Yes
EPM	0.198	Manager	No
OE	0.186	Manager	No
EPCS	0.186	Supervisor	No
EPIS	0.186	Supervisor	No
EPTS	0.186	Supervisor	No

Figure 26 indicates the management level having the lowest level of betweenness although being responsible for communication among different departments. The supervisor and staff levels were shown to be best placed for enhancing the flow of information throughout the organization. However, these two groups had no formal communication or decision-making authority and accounted for 65% of the cognitive demand. The consequence of this approach to communication impacts project performance in two significant ways: the tangible impact of delay, as formal feedback cannot take place in real time, and diminishment of the behavioral dimension of trust due to a perception of parties not being transparent with each other (Lencioni 2007).

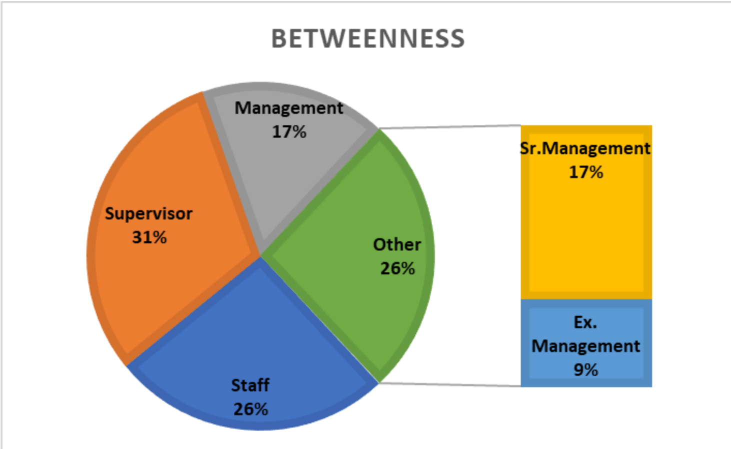


Fig. 26. Betweenness by organization level.

Align Priorities and Objectives

Involvement of the key agents in the pre-FEED stage of the project development cycle is critical to project success to ensure that all project requirements are clearly defined and finalized (Kerzner 2009; Muiño and Akselrad 2009). The tasks requiring input from the broadest range of agents are identified as those with the highest values of in-degree centrality. Figure 27 shows the simulation results for the level of input (descriptors are listed in Table 38) required for the various pre-FEED stage project tasks. The basis of design and the manpower plan are the tasks with the highest values of in-degree centrality and are foundational to aligning work priorities and project objectives. Out-degree centrality provides a measure of the level of input required by each of the stakeholders. The operations division would become the project custodian after completion, making their representatives' (OE, OM, and OP on Figure 28) involvement and input critical success factors.

Table 38. Task descriptors

Task	Description
GE1	Basis of design
PR1	Process flow diagrams
PR2	Utility flow diagrams
PR3	Preliminary P&IDs
PR4	Technical HSE guidelines
ME1	Major equipment data sheets
ME2	Equipment lists
CS1	Preliminary foundation design
CS2	Preliminary structural steel design
PP2	Piping layouts
IC1	Updated control philosophy
IC2	Instrument list
EE1	Preliminary one-line design
EE2	Preliminary area classification
EE3	Updated power requirements
EE4	Preliminary electrical equipment list
PM1	Project execution plan
PM2	Assurance plan
PM3	Constructability review
PM4	Manpower plan
PM5	Contracting and strategy plan
PS1	Project schedule
PS2	Budget
PS3	Cost estimate
OP1	Operability and maintainability philosophy
MRE1	Decision support pack

Note. P&ID = piping and instrumentation diagram

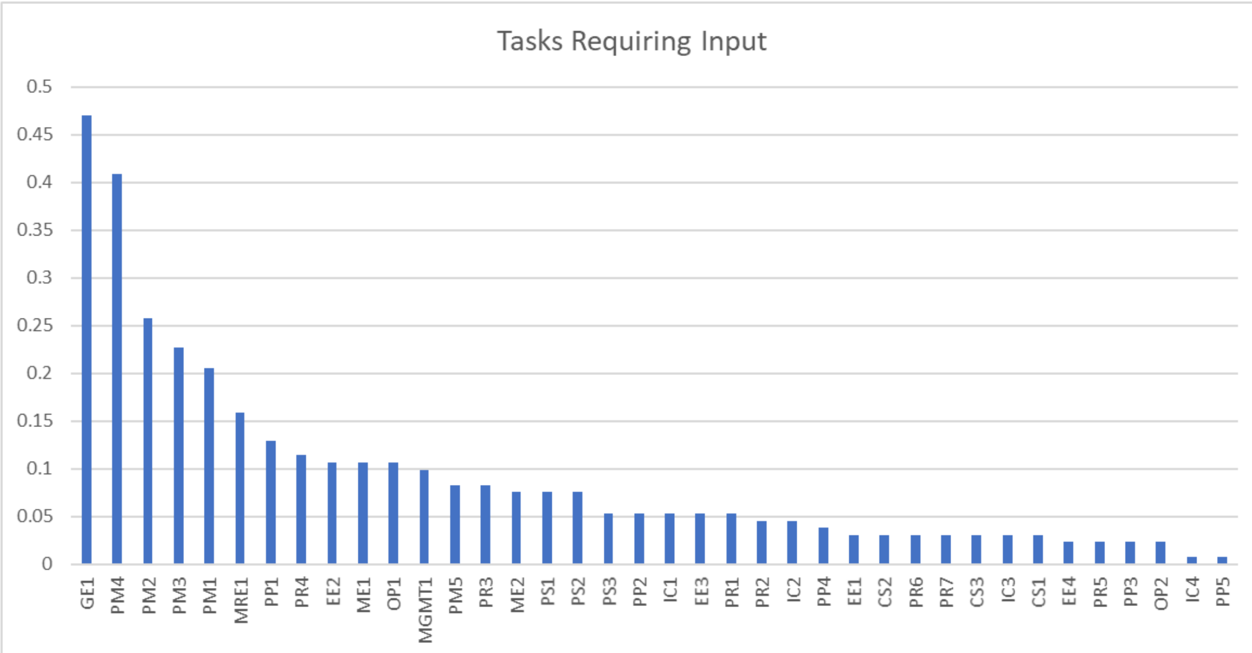


Fig. 27. Project task stakeholder input levels based on in-degree centrality. (Task descriptors are shown in Table 38.)

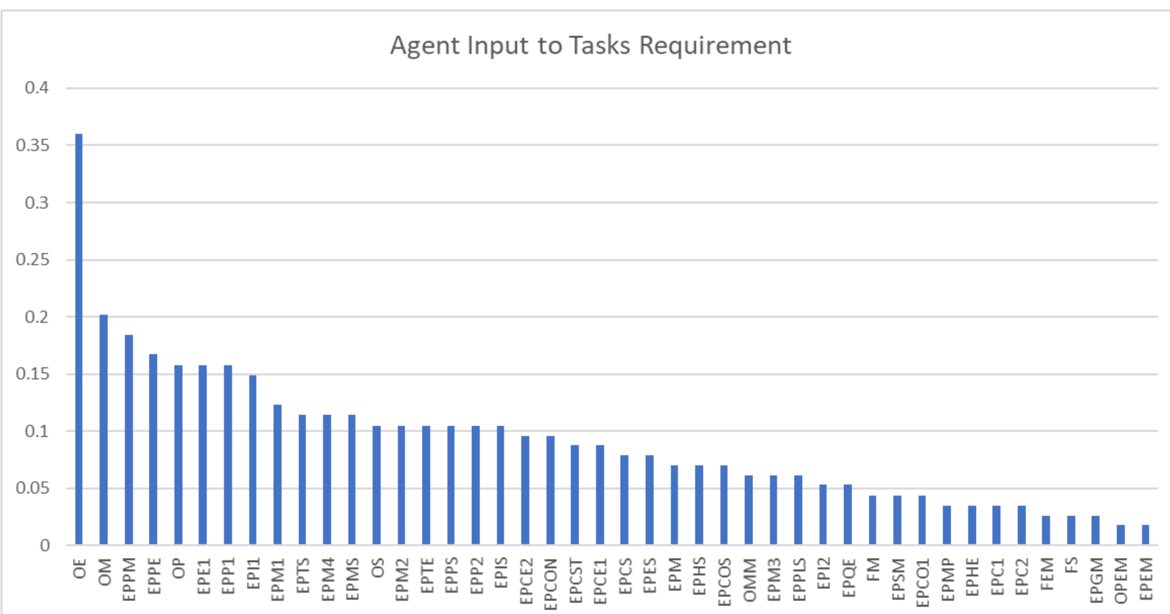


Fig. 28. Agent-required input level for project tasks based on out-degree centrality. (Organization labels are shown in Table 32.)

In the metanetwork, the communication network provided insight regarding agent interaction with each other, and the activation network identified agent influence on causal factors. Consequently, agents who should be providing input and are able to influence causal factors should be involved in project development—especially if they have an ongoing role in the project after completion. The results from the simulation (Figure 29) indicated agents influencing the highest number of causal factors (agents from operations and finance) to also be the least involved in the overall communication network. This is consistent with feedback from interviews and the survey, providing further support regarding the utility of the model.

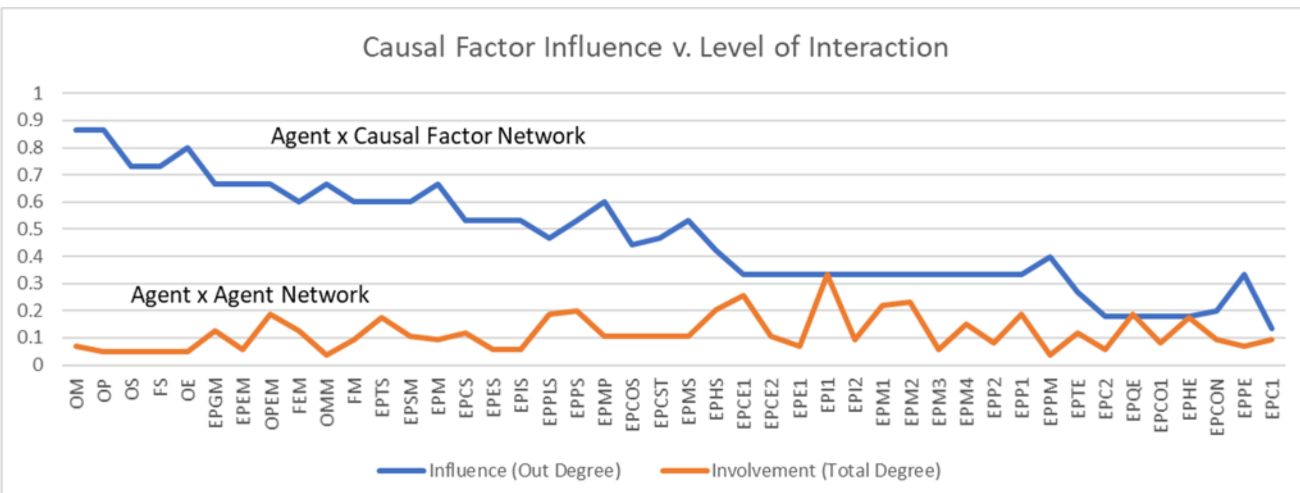


Fig. 29. Comparison of causal factor influence of stakeholders vs. stakeholder interaction. (Organization labels are shown in Table 32.)

Impact Teamwork

A consistent theme in all of the OilCo feedback was the lack of teamwork among the various stakeholder group representatives with regard to project delivery. The OilCo organizational structure can be described as functional silos, with information moving vertically upward to the management level (or above), then horizontally across, and finally vertically downward in the targeted division. This type of formality is not conducive to establishing a sense of team connectivity. The network measure of potential boundary spanner identifies the agents best placed to connect unconnected groups. Table 39 shows the agents with the highest values for potential boundary spanner, indicating their being in the best position to be bridges to increase organizational connectivity. Aligning the OE and engineering manager (EPM) roles, along with the senior management roles of manager of project management (EPMP) and manager of operations (OMM), provides an opportunity to enhance organizational teamwork.

Table 39. Agents and organization levels with the highest values of potential boundary spanner with authority level

Agent	Potential boundary spanner	Organization level	Decision authority
EPMP	0.08	Senior manager	Yes
OE	0.061	Manager	No
EPM	0.055	Manager	No
EPPE	0.054	Staff	No
EPMS	0.053	Supervisor	Yes
EPPM	0.051	Manager	No
OMM	0.048	Senior manager	Yes
EPCST	0.045	Supervisor	No
EPIS	0.043	Supervisor	No
FS	0.041	Supervisor	No

In addition to the individual roles identified, the supervisory level was shown to have the highest level of connectivity across the organization and to be best placed, along with the staff, to foster teamwork. Figure 30 highlights the supervisory and staff levels having the greatest ability to create bridges between the stakeholder groups. Identifying organizational adjustments specifically addressing the OE and EPM roles and leveraging the supervisory level have the potential to enhance teamwork.

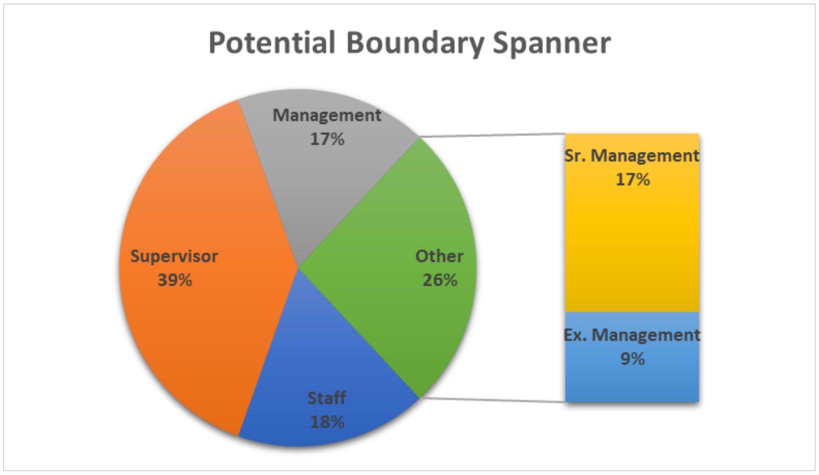


Fig. 30. Boundary spanner by organization level.

Challenge the Culture

Challenging and changing corporate culture are disciplines in themselves and are beyond the scope of this research. However, to change culture requires consistent flow of information and reinforcement. The network analysis measure eigenvector identifies the nodes that are connected to the most connected nodes. Consequently, these nodes are capable of disseminating or cascading information most effectively. The eigenvector network analysis measure in this instance indicated the agents with the ability to effectively cascade the required elements to challenge the culture. Table 40 shows the agents with the highest eigenvector values. Both Table 40 and Figure 31 show the supervisory level being best placed to cascade cultural change through the organization. Additionally, the OE and EPM roles emerged as leverage points for enhancing interdivision alignment and engagement.

Table 40. Agents and organization levels with the highest values of eigenvector with authority level

Agent	Potential boundary spanner	Organization level	Decision authority
EPMS	0.42	Supervisor	No
EPPS	0.413	Supervisor	No
EPPE	0.413	Staff	No
EPM	0.409	Manager	No
EPTS	0.399	Supervisor	No
EPCS	0.388	Supervisor	No
EPES	0.376	Supervisor	No
EPIS	0.37	Supervisor	No
OE	0.357	Manager	No
EPMS	0.42	Supervisor	No

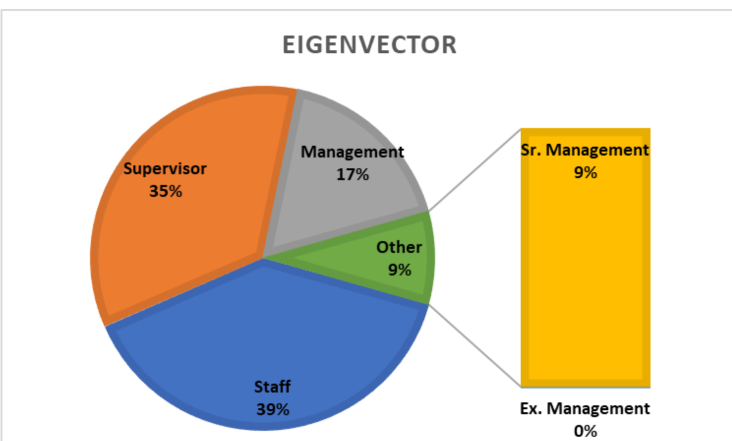


Fig. 31. Eigenvector by organization level.

In summary, agents without authority (management, supervisor, and staff) were shown to occupy ca. 75 to 90% of influential structural positions. Of this group, the supervisory level was shown to be best placed to affect alignment of objectives, enhance communication, improve teamwork, and lead cultural change. However, this level also was shown to be the portion of the population having the highest levels of responsibility and workload without authority. The supervisory level was proven integral to making gains in the opportunity areas, and, consequently, organizational modifications that effectively address the responsibility-without-authority and cognitive demand challenges were shown to require evaluation. More specifically, the OE and EPM roles emerged as key points of leverage, which should be taken into consideration for all organizational modification opportunities.

Evaluation

This stage of the analytical framework addressed the research question: Can the framework, tools, and measures be validated in an active project portfolio for an energy firm and specific recommendations be identified to mitigate specific behavior-centric intangible risks? Using the measures from the previous identification phase, this stage used MNA to identify organizational modifications that can be implemented in an active project portfolio setting. This addresses the current literature gap of no empirically validated behavior-centric intangible risk assessment and implementation in an actual corporate project setting.

The identification-phase network analysis measures pointed to the supervisory levels of engineering and operations being best placed to enhance communication and teamwork within OilCo, with the manager positions of OE and EPM being a focus for organizational enhancement. However, these roles faced the burden of having to balance issues that arise between departments while meeting management expectations for project delivery using personal influence as their only means of persuasion. The following highlights the conundrum faced by these agents. In one instance, a project was delayed for three months because of scope interpretation before finally being escalated for senior management intervention and closure. In the first postcompletion project workshop, the researcher asked, "Why did it take so long to escalate the matter to management?" The response from the supervisory level involved was, "We felt that raising the issue would be seen as a lack of ability to do our jobs by our individual managers." The researcher followed up with the question, "In hindsight, what would have been the best course of action to preserve value for OilCo?" The response was, "If I focus on what is best for OilCo, I am likely receive an average performance review; however, if I focus on what is best for my department, regardless of the implications for OilCo, then I am likely to get a higher rating." This highlights the potential implications of a cross-organizational issue when a single point of accountability is absent. In this case, the lack of authority along a single point of accountability made effective decision making complicated and created significant stakeholder misalignment (causal factor RT9) and a culture where blame and avoiding responsibility (causal factor RT7) became pronounced. The challenge of responsibility without authority and its impact on project team effectiveness was a consist theme in all project workshops, as well as the management workshop.

OilCo went through a significant reorganization a few years prior to this assessment. The reorganization had two significant impacts: headcount reductions of 20 to 25% in all divisions and a realignment of the engineering function. In the operations organization, all engineers from production, maintenance, and technical support were consolidated into a new entity named operations engineering (OE). The operations safety (OS) group maintained its technical staff. Along with this reduction was a refocusing of the production operations and maintenance responsibilities that made no provision for project support, either during project development (e.g., commenting on statement of requirements) or execution (e.g., providing necessary site support). This responsibility was given to the OE organization to be the interface with the project (EPPM) and engineering (EPM) organizations for all matters. However, the production operations (OP) and maintenance operations (OM) organizations maintained the authority to accept the final project, and the OE, EPPM, and EPM organizations had no authority or influence in the event that OP or OM required changes to the installed facility.

Based on the experiences from the previous reorganization, the executive management required that any proposed changes to the organization stemming from this assessment hold a "proven" construct and not cause a material distraction to the staff. To meet this requirement, the working team approached OilCo's joint venture partners (JVPs) to discuss their organizational approach to support project development and delivery. The consistent message from the discussions was the need for a single point of accountability with the delegated authority for project development and delivery from all divisions. The potential modifications to the existing OilCo organization from these discussions were:

- Creation of a new organizational division called operations integration and initiation (OII) that reports to the vice president of operations and serves as the single point of accountability for project requirements and the interfaces required for effective delivery
- Disbandment of the OE organization and reassignment of staff to OP, OM, and OII
- Assignment of senior staff from OP and OM to OII and formal empowerment of OII by the vice president of operations to make all decisions on behalf of all operating divisions and have oversight of engineering design
- Reporting of EPM and the appropriate engineering support to OII for large projects (more than $50 million) in a matrix structure from pre-FEED through execution

The proposed organizational structure is shown in Figure 32.

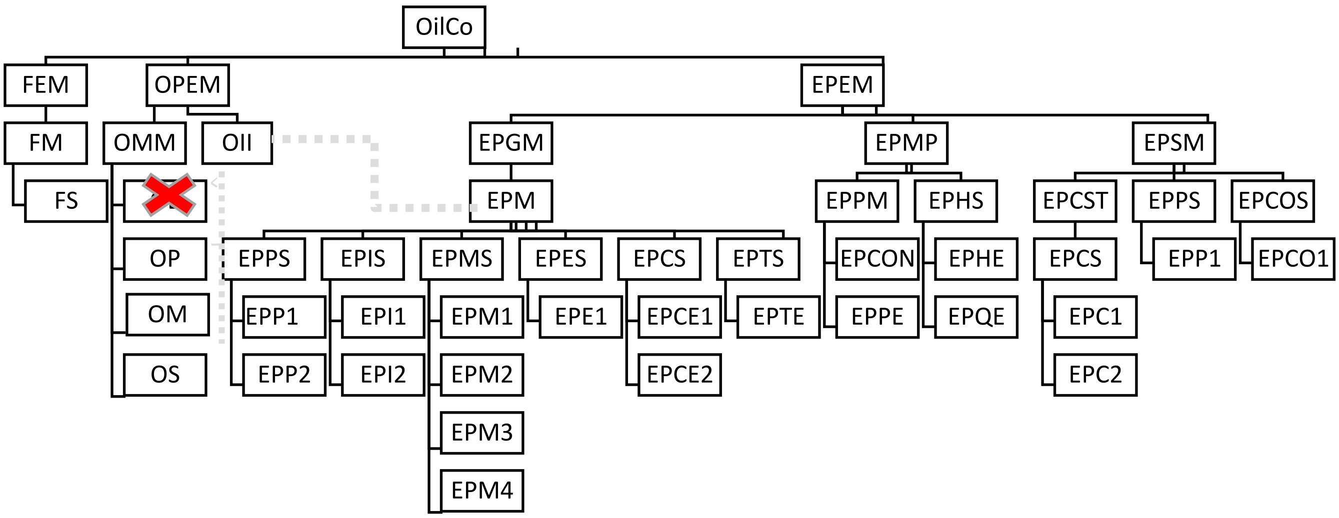


Fig. 32. OilCo modified organizational construct based on JVP feedback.

The most significant proposed modification is replacing the existing management level OE role and organization with a newly created senior management role, OII, and the establishment of the matrix reporting relationship of EPM to OII. Comparing the OII to OE network analysis measures, the proposed organization has the capacity to address the current gap in project performance effectively. The potential organizational modifications were simulated and the resulting network analysis measures compared to those of the existing organization to provide a quantitative basis to support the organizational proposal to executive management. A comparison of the measures is shown in Table 41.

Table 41. Network analysis measure comparison for OE and OII

Network analysis measure	OE	OII	Change
Betweenness	0.116	0.459	296%
Eigenvector	0.357	0.56	57%
Potential boundary spanner	0.061	0.143	134%
Total degree	0.186	0.453	144%
Cognitive demand	0.253	0.355	40%

The significant increase in betweenness and seniority from the OE to OII role has the potential to enhance the flow of information across the organization and increase decision-making efficiency. Additionally, there is a considerable ripple effect across the organization. Figure 33 shows the changes in betweenness between the original and proposed OilCo organization configurations.

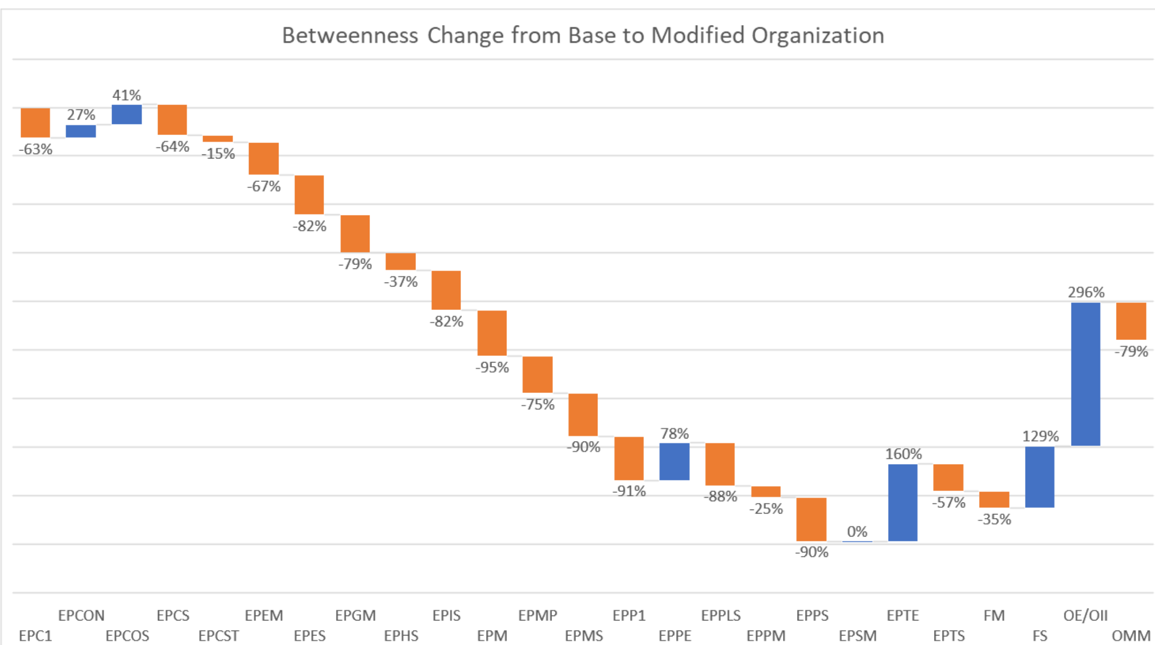


Fig. 33. Comparison of the change in network betweenness for proposed organization compared to original organization. (Clarify roles, responsibilities, and authorities; increase communication effectiveness and decision making; align priorities and objectives; impact teamwork; challenge the culture.)

The increase in betweenness (+129%) of the finance supervisor will increase the flow of information to the finance department and provide the opportunity for a more effective working relationship. The initial survey result comparison between key divisions (Figure 16) showed the support functions having lower confidence in several of the behavioral risk areas. Also, the project engineer (+78%), technical HSE (+160%), construction (+27%), and contract roles (+41%) become more prominent in the proposed network, providing a more efficient path for their input during project definition and development. This can reduce re-cycling of engineering documents by ensuring that the input from these key functions is included early in the design.

While increasing betweenness for key roles has positive implications, decreasing it for noncritical roles can increase development efficiency and enhance human resource allocation by reducing the need for involvement in project activities that don't specifically require their expertise. The lack of clarity regarding roles and responsibilities in OilCo was causing many staff and supervisors to attend meetings to ensure that there were no misunderstandings. Much of the reduced betweenness, or said another way, involvement, is in the supervisor and manager levels of the organization, which can help with reducing the manifestation of NAG and behavior-centric intangible risk factors (e.g., wasting time managing behaviors for effect [IRF5]). Finally, the OII role and reduction of the involvement of the supervisors and managers reduce the propensity for role and responsibility misunderstanding and the political issues that can arise. This can be seen in the change in the network analysis measures (Table 42) for the EPM role between the original organizational structure and the proposed organization with the matrix reporting relationship with the OII role. The significant reduction in betweenness and potential spanner is caused by the EPM role having a single point of accountability (OII) for projects. This new reporting relationship provides focus and reduces the need to interface with multiple agents in the project development process. The other measures are essentially the same, indicating that the roles' ability to cascade information, workload, and level of involvement has not changed. Simply put, this change makes the EPM role more efficient without changing the core contributions.

Table 42. Network analysis measure comparison between the original and proposed organizational structures for EPM role

Network analysis measure	Current	Proposed	Change
Betweenness	0.111	0.006	–95%
Eigenvector	0.409	0.369	–10%
Potential boundary spanner	0.055	0.005	–91%
Total degree	0.198	0.209	6%
Cognitive demand	0.13	0.13	0%

The OII role has the requisite authority to make decisions regarding project requirements and is also accountable for the project's final acceptance. The impact of this can be seen in the comparison of influence and involvement (Figure 34) before and after the OII modification, where the gap between influence and involvement is reduced by more than half. This will provide a higher level of representation in project development from those who have the ability to better align priorities and objectives. In addition to the network analysis measures, the ability of the OII to have an impact on the risk causal factors was discussed with the management team, and the consensus is presented in Table 43.

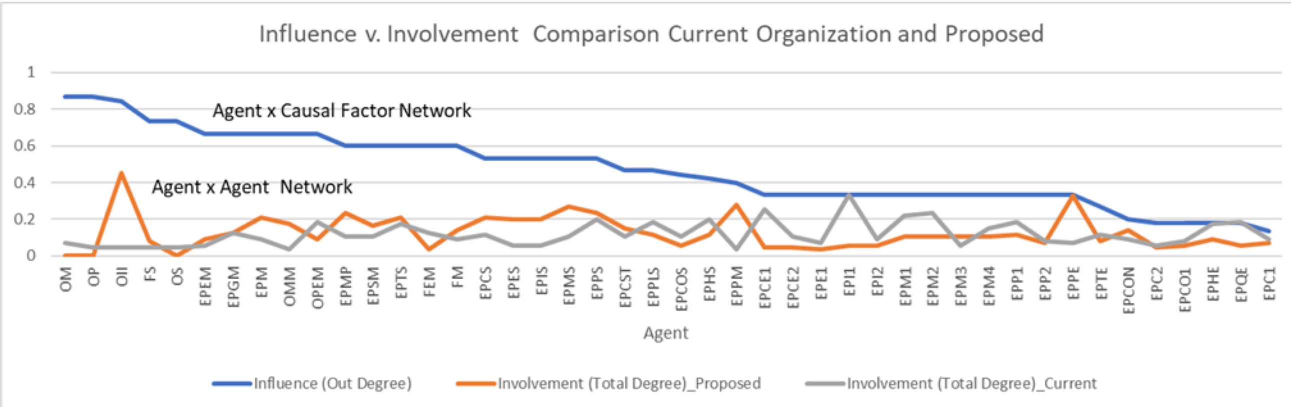


Fig. 34. Comparison of influence vs. involvement for original vs. proposed organizational constructs.

Table 43. OII ability to influence risk causal factors vis-à-vis OE

Indicator	Risk causal factor	OII vs. OE ability to influence
RT1	Lack of clearly defined goals and objectives	Higher
RT2	Lack of active management support	Higher
RT3	Improperly defined/agreed priorities	Higher
RT4	Poorly defined roles and responsibilities	Higher
RT5	Inadequate or vague requirements	Higher
RT6	Insufficient organizational structure for scope of work	Higher
RT7	Culture (punitive, insecure)	Same
RT8	Ineffective decision making	Higher
RT9	Key stakeholder misalignment	Higher
RT10	Contradicting interpretations of internal policies and procedures	Same
RT11	Inappropriate risk tolerance	Same
RT12	Ineffective communication	Higher
RT13	Inability to change or accept change	Same
RT14	Meeting key stakeholder expectations	Higher
RT15	Inadequate review processes	Higher

The increases in the network analysis measures of potential boundary spanner and total degree indicate the OII role having the network structural position to bring groups together and the authority to enact change. Additionally, the increase in the eigenvector measurement highlights the ability to cascade information. These are essential in addressing the gap in teamwork, as well as having the ability to impact the current culture. The OII network modification meets the executive management requirement of leveraging a proven concept, it does not have a material physical impact on the organization that would cause a distraction to the staff, and it has the potential to effectively address all of the opportunity areas.

Recommendation

A presentation was made to the OilCo executive team (executive vice presidents from all OilCo divisions) highlighting the feedback from all the workshops and the high-level messages from the simulation. Three high-level organizational recommendations were made:

- Creation of a new organizational division (OII) that reports to the vice president of operations and serves as the single point of accountability for project requirements and the interfaces required for effective delivery, along with disbandment of the OE organization and reassignment of staff to OP, OM, and OII, to address the gap between influence and involvement while freeing the supervisory level to utilize its advantaged centrality position to enhance organizational communication and teamwork
- Assignment of senior staff from OP and OM to OII and formal empowerment of OII by the vice president of operations to make all decisions on behalf of all operating divisions and have oversight of engineering design, which can have a positive impact on aligning priorities and objectives throughout the organization to enhance project delivery
- Reporting of EPM and the appropriate engineering support to OII for large projects (more than $50 million) in a matrix structure from pre-FEED through execution, which will enhance the overall decision-making process, as well as providing more clarity regarding roles and responsibilities

Implementation

The results of the simulation were presented to the steering committee, indicating that a change in the organization should mitigate a majority of the causal factors. Based on the IRAMP assessment and the organizational modification not being viewed as causing disruption to business delivery, the decision was made to proceed with creation of the OII role and organization. At the time of this writing, the OilCo OII manager has been named, and the OII organizational construct has been approved for recruitment.

CHAPTER VIII

CONCLUSIONS, LIMITATIONS, AND FURTHER RESEARCH

Introduction

This chapter addresses the conclusions from this research, its limitations, and opportunities for further investigation. The goal of this research was to develop and validate a rigorous, user-friendly framework to identify behavior-centric intangible risks and the conditions that initiate them throughout the project development cycle. Meeting this goal would provide an answer to the overarching research question: Would the development of a framework to identify, assess, and quantify behavior-centric intangible risks enhance project and portfolio risk identification and assessment?

Conclusions

The case study demonstrates how the IRAMP and MNA can be used to identify behavior-centric intangible risks and their causal factors and structural opportunities in organizations for improving project performance. The feedback from the participants in the case study, as well as the industry SME workshop, was highly supportive of this research. All of the participants indicated the framework and simulation having the potential to add significant value to project development and delivery by highlighting the behavioral risks and their causal factors early in the project cycle and providing an objective approach to proactively managing them. In addition to the prospective impacts on projects and portfolios of projects, they indicated that the framework could be applied in other areas (e.g., corporate team-building exercises) beyond projects and portfolios of projects. This provides an affirmative answer to the overarching research question. This section links each research objective with its hypothesis, case study application, results, and conclusions.

Objective 1

Formulate an analytical framework that can be used in project risk workshops to effectively identify and assess behavior-centric intangible risks in projects and project portfolios. This framework will be integrated into existing risk management processes for each stage in the project development cycle.

- *Hypothesis 1*: The development of a framework for use in identifying and prioritizing behavior-centric intangible risks will enhance the overall quality of risk management for projects and project portfolios.
- *Application*: Apply the IRBS, causal factor checklist, and RIM in an active project portfolio setting to identify and prioritize behavior-centric intangible risks for all stages of the project development cycle.

Results

Ten workshops were organized and facilitated by the researcher to identify the behavior-centric intangible risks and causal factors most prevalent in OilCo projects. Six of these workshops were with project teams from completed projects, three with teams whose projects were in progress (portfolio projects), and one with senior management. The combined attendance was 150 OilCo staff (ca. 120 technical and supervisory staff and 30 senior managers), representing more than three millennia of industry experience. All project team participants found the process and the results to be very useful because a structured approach was provided to address difficult behavioral topics. The management team participants felt the process to be more valuable than the actual results because it provided a framework to enhance the risk management process.

Conclusions

The IRBS, causal factor checklist, and RIM (i.e., IRAMP) are effective and user-friendly, evidenced by the feedback from the case study participants and the industry SME workshop. These tools provide a structured approach to addressing the behaviors referred to by Rasmussen as "idiosyncratic and unpredictable" (Rasmussen 1997). The structured approach to addressing behavior-centric intangible risks and their causal factors creates a nonpolitical opportunity to align management and project teams in proactively addressing the threats and opportunities they present. Incorporating this framework into the existing risk management process enables project and portfolio teams to identify and prioritize the behavior-centric intangible risks and the associated causal factors for their particular projects. Additionally, the IRAMP has the potential to enhance overall project communication by providing a nonthreatening approach to discuss the "elephant in the room" during risk identification sessions and the ongoing reporting. This research opens a new vista in assessment of the less tangible risks associated with behaviors and their causal factors and addresses a gap in project risk management.

Objective 2

Identify appropriate analytical tools and network measures of centrality (e.g., betweenness, cognitive demand, etc.) to quantify behavior-centric intangible risks. These measures will be used to provide insights regarding potential organizational or procedural modifications for project performance enhancement.

- *Hypothesis 2*: A quantitative approach to characterize behavior-centric intangible risks, along with appropriate measures, increases the likelihood of projects meeting their objectives.

- *Application*: Develop a metanetwork for an international oil and gas firm, and use simulation results to assess the behavior-centric intangible risks and causal factors in an actual organization. Use ORA-PRO simulation software and identify existing SNA measures appropriate for quantifying behavior-centric intangible risks, agent attributes, and causal factor influences.

Results

The OilCo-specific metanetwork for the research case portfolio of projects and six network analysis factors were identified. Simulation results provided quantitative support for what had become an open secret at OilCo—responsibility without authority was creating "wicked messes" (Roth and Senge 1996). The agents were ranked by their scores for each of the network measures (betweenness, cognitive demand, eigenvector, potential boundary spanner, and total degree), with the underlying message that agents without authority were occupying ca. 75 to 90% of influential structural positions. Looking at workload using the network analysis measure of cognitive demand indicated 90% of work being the responsibility of agents with no formal authority. The majority of the effort was sitting with the supervisor level, confirming that the agents with responsibility did not have the commensurate authority to be effective. However, the level above them, while having less direct project-related workload, was not empowered to make decisions.

Ensuring that key stakeholders are involved so that project requirements can be clearly defined and finalized in the pre-FEED stage is critical to project success. Simulation results revealed the agents with the most influence on causal factors and indicated the agents influencing the highest number of causal factors to also be the least involved in the overall communication network.

Conclusions

Leveraging network analysis measures developed for SNA can provide robust results for assessing the implications of behavior-centric intangible risks and can highlight opportunities to address organizational issues influencing them. The use of indicative quantitative measures creates an objective foundation to explore solutions and prioritize risk response activities. Increasing communication and alignment with stakeholders can increase the ability of a project team to meet its objectives. Finally, these measures can be used as benchmarks and the basis for lessons learned in future projects.

Objective 3

Empirically validate the proposed tools and measures in an active portfolio of projects for an oil and gas corporation and provide specific recommendations for mitigating identified risks.

- *Hypothesis 3*: A framework and quantitative approach developed for projects and project portfolios can be applied to each stage of the project development cycle and can enhance overall risk management effectiveness.
- *Application*: Empirically validate IRAMP as a reasonable surrogate to holistically assess organizational modifications prior to implementation.

Results

To properly address the intangible risks associated with the existing organizational construct, proposed modifications were simulated, and the network analysis measures of the original organization and the proposed modifications were compared. These comparisons were used to provide assurance for the decision makers. The creation of a new department (OII), with appropriate levels of authority and job scope underpinned by material increases in all network analysis measures, is a significant organizational enhancement. Increasing betweenness for key roles while decreasing it for noncritical roles can strengthen communication and enhance human resource allocation. The creation of OII results in a significant change (ca. +300%) in betweenness as compared to the original construct with OE, as well as increasing communication with the finance division (ca. +130%). This organizational change provides the network with agents (OII and finance) with sufficient authority to enhance information flow, as well as having a level of influence to become effective "brokers" for supporting teamwork and beneficial effects on the existing culture. This result was supported by executive management and was implemented.

Conclusions

The use of MNA in a real-world corporate setting to assess project behavior-centric intangible risks and simulate proposed modifications is validated. ORA-PRO simulation software and network analysis measures provide valuable insight to project teams and managers in a portfolio context. Assessment by project stage highlights the importance of early involvement by key stakeholders and the need to clearly define requirements for projects; otherwise, cascading behavior-centric risks will likely occur. Additionally, the use of simulation provides executive management with a level of assurance that proposed organizational changes are capable of addressing issues of project performance.

Research Contributions

This research contributes to the field of risk management in several significant ways. First, it introduces IRAMP as a new empirically based framework for the identification of behavior-centric intangible project risk throughout the development cycle. Second, it pioneers the inclusion of behavior-centric intangible risks and the conditions that cause them in a metanetwork construct, creating the ability to use dynamic network simulation models. Network analysis measures are identified for use in quantifying the implications of events and their influence on behavior-centric risks. These quantitative measures identify relationships within the metanetwork and the implications of making modifications. The ability to make the subjective objective enhances the overall effectiveness of the risk management process.

Research Limitations

While the research provided robust results in the OilCo case study, several limitations must be considered for future applications:

- The empirical results came from a single corporate project portfolio with a distinctive culture.
- The data collected from the ex-post projects required participants to refer back to causal factors and behaviors that had occurred months or even a year before the workshop. This may have caused inaccurate information due to recall bias or memory lapse.
- The information regarding the behavior-centric intangible risks, their causal factors, and the agent interactions by stage was collected from three different projects with completely different teams. This approach cannot accurately reflect how these risk and causal factors emerge from individual project stage to individual project stage.
- The portfolio meta-analysis was limited to the three projects used in the project stage analysis and does not represent the overall portfolio balance.

Future Research Opportunities

The industry SME validation workshop feedback was very supportive of this research having the ability to add significant value to all of the organizations represented in the workshop. Several participants highlighted the ability of this research to be applied outside of projects to other areas such as the business planning process. This research can be exended to several areas where the connection to project performance is direct or indirect (e.g., increasing corporate internal processes, etc.):

- Longitudinal study of a collection of different-size energy firms can provide a diverse dataset for assessing the IRAMP and the network analytical measures.
- Opportunity exists to investigate other cognitive frameworks that can be better tailored to a firm's specific behavior-centric circumstances. This will require transdisciplinary cooperation with organizational psychologists to develop a diagnostic rubric.
- Opportunity exists to extend this research to the enterprise level incorporating behavior-centric intangible risks and their causal factors in strengths, weaknesses, opportunities and threats (SWOT) analysis for the business planning process. This approach is also applicable to organizational efficiency assessments and corporate reengineering efforts to identify opportunities for improvement or areas of potential resistance. The use of simulation can provide a means to assess intervention impacts prior to initiating any change.
- There are implications of artificial intelligence on behavior-centric intangible risks and causal factors. Higher cognitive skills and creativity will be required, along with more emphasis on effective teamwork. This requires a conducive workplace and an appropriate leadership style linking it to the research stream of cognitive diagnostic frameworks.

REFERENCES

Afraimovich, V., T. Young, M. K. Muezzinoglu, and M. I. Rabinovich. 2011. "Nonlinear dynamics of emotion-cognition interaction: When emotion does not destroy cognition?" *Bull. Math. Biol.*, 73 (2), 266–284.

Ancona, D. G., T. A. Kochan, M. A. Scully, J. Van Maanen, and D. E. Westney. 1999. *Managing for the future: Organizational behavior & processes* (2nd ed.). Mason, OH: South-Western College Publishing.

Archibald, R. D. 2017. "Five decades of modern project management: Where it came from – Where it's going." *PM World Journal*, 6 (1).

Atkinson, R. 1999. "Project management: Cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria." *Int. J. Project Manage.*, 17 (6), 337–342. https://doi.org/10.1016/S0263-7863(98)00069-6/.

Atkinson, R., L. Crawford, and S. Ward. 2006. "Fundamental uncertainties in projects and the scope of project management." *Int. J. Project Manage.*, 24 (8), 687–698. https://doi.org/10.1016/j.ijproman.2006.09.011/.

Aubry, M., and S. Lenfle. 2012. "Projectification: Midler's footprint in the project management field." *International Journal of Managing Projects in Business*, 5 (4), 680–694. https://doi.org/10.1108/17538371211268997/.

Aven, T., Y. Ben-Haim, H. B. Andersen, T. Cox, E. L. Droguett, M. Greenberg, S. Guikema, W. Kröger, O. Renn, K. M. Thompson, and E. Zio. 2018. *Society for risk analysis glossary*. Herndon, VA: Society for Risk Analysis. https://www.sra.org/sites/default/files/pdf/SRA%20Glossary%20-%20FINAL.pdf/.

Baccarini, D. 1996. "The concept of project complexity—A review." *Int. J. Project Manage.*, 14 (4), 201–204. https://doi.org/10.1016/0263-7863(95)00093-3/.

Bankolli, V. M., and K. Jain. 2014. "Interplay of tangible and intangible factors in project management: A case study of a marine project." In *Proc., 3rd International Scientific Conf. on Project Managmenet in the Baltic Countries*, 7–21. Riga, Latvia: University of Latvia.

Barabási, A.-L. 2016. *Network science*. Cambridge, UK: Cambridge University Press.

Barber, R. B. 2005. "Understanding internally generated risks in projects." *Int. J. Project Manage.*, 23 (8), 584–590. https://doi.org/10.1016/j.ijproman.2005.05.006/.

Basu, C. 2017. "A summary of tangible & intangible risks." *bizfluent,* September 26, 2017. https://bizfluent.com/info-7996114-summary-tangible-intangible-risks.html/.

Belassi, W., and O. I. Tukel. 1996. "A new framework for determining critical success/failure factors in projects." *Int. J. Project Manage.*, 14 (3), 141–151. https://doi.org/10.1016/0263-7863(95)00064-X/.

Beringer, C., D. Jonas, and A. Kock. 2013. "Behavior of internal stakeholders in project portfolio management and its impact on success." *Int. J. Project Manage.*, 31 (6), 830–846. https://doi.org/10.1016/j.ijproman.2012.11.006/.

Bernstein, P. L. 1998. *Against the gods: The remarkable story of risk.* New York, NY: John Wiley & Sons.

Bienenstock, E. J., P. Bonacich, and M. Oliver. 1990. "The effect of network density and homogeneity on attitude polarization." *Social Networks*, 12 (2), 153–172. https://doi.org/10.1016/0378-8733(90)90003-R/.

Blichfeldt, B. S., and P. Eskerod. 2008. "Project portfolio management – There's more to it than what management enacts." *Int. J. Project Manage.*, 26 (4), 357–365. https://doi.org/10.1016/j.ijproman.2007.06.004/.

Bordage, G. 2009. "Conceptual frameworks to illuminate and magnify." *Med. Educ.*, 43 (4), 312–319. https://doi.org/10.1111/j.1365-2923.2009.03295.x/.

Borgatti, S. P. 2005. "Centrality and network flow." *Social Networks*, 27 (1), 55–71. https://doi.org/10.1016/j.socnet.2004.11.008/.

Brockman, J. L. 2014. "Interpersonal conflict in construction: Cost, cause, and consequence." *J. Constr. Eng. Manage.*, 140 (2): 04013050. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000805/.

Carl, J. W., and G. R. Freeman. 2010. *Nonstationary root causes of Cobb's paradox*. Fort Belvoir, VA: Defense Acquisition University. https://apps.dtic.mil/dtic/tr/fulltext/u2/a523877.pdf/.

Carley, K. M. 2002. "Computational organizational science and organizational engineering." *Simul. Modell. Pract. Theory*, 10 (5–7), 253–269. https://doi.org/10.1016/S1569-190X(02)00119-3/.

Carley, K. M., J. Diesner, J. Reminga, and M. Tsvetovat. 2007. "Toward an interoperable dynamic network analysis toolkit." *Decision Support Systems*, 43 (4), 1324–1347. https://doi.org/10.1016/j.dss.2006.04.003/.

Carley, K. M., J. Pfeffer, J. Reminga, J. Storrick, and D. Columbus. 2013. *ORA user's guide 2013*. Pittsburgh, PA: Carnegie Mellon University.

Chapman, C. B., and S. Ward. 2003. *Project risk management: Processes, techniques and insights*. Hoboken, NJ: John Wiley and Sons.

Chapman, R. J. 2001. "The controlling influences on effective risk identification and assessment for construction design management." *Int. J. Project Manage.*, 19 (3), 147–160. https://doi.org/10.1016/S0263-7863(99)00070-8/.

Chinowsky, P., J. Diekmann, and V. Galotti. 2008. "Social network model of construction." *J. Constr. Eng. Manage.*, 134 (10), 804–812. https://doi.org/10.1061/(ASCE)0733-9364(2008)134:10(804)/.

Chinowsky, P., J. E. Taylor, and M. Di Marco. 2011. "Project network interdependency alignment: New approach to assessing project effectiveness." *J. Manage. Eng.*, 27 (3), 170–178. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000048/.

Clark-Ginsberg, A. 2017. "Participatory risk network analysis: A tool for disaster reduction practitioners." *Int. J. Disaster Risk Reduct.*, 21, 430–437. https://doi.org/10.1016/j.ijdrr.2017.01.006/.

Clark-Ginsberg, A., L. Abolhassani, and E. A. Rahmati. 2018. "Comparing networked and linear risk assessments: From theory to evidence." *Int. J. Disaster Risk Reduct.*, 30, 216–224. https://doi.org/10.1016/j.ijdrr.2018.04.031/.

Connolly, M., and R. Rianoshek. 2002. *The communication catalyst: The fast (but not stupid) track to value for customers, investors, and employees*. Boulder, CO: Conversant Solutions.

Cook, R., and J. Rasmussen. 2005. "'Going solid': A model of system dynamics and consequences for patient safety." *Quality and Safety in Health Care*, 14 (2), 130–134. https://doi.org/10.1136/qshc.2003.009530/.

Costello, T. 2012. "RACI—Getting projects 'unstuck.'" *IT Prof.*, 14 (2), 64. https://doi.org/10.1109/MITP.2012.41/.

Danilovic, M., and B. Sandkull. 2005. "The use of dependence structure matrix and domain mapping matrix in managing uncertainty in multiple project situations." *Int. J. Project Manage.*, 23 (3), 193–203. https://doi.org/10.1016/j.ijproman.2004.11.001/.

Dargin, S. 2013. "Making intangibles tangible: adapting project management tools for coaching." In *Proc., PMI Global Congress 2013 – North America*. Newton Square, PA: Project Management Institute.

Davis, M. 2020. "The 8 most volatile sectors." www.investopedia.com/financial-edge/0712/the-8-most-volatile-sectors.aspx/.

De Jong, B. A., K. T. Dirks, and N. Gillespie. 2016. "Trust and team performance: A meta-analysis of main effects, moderators, and covariates." *Journal of Applied Psychology*, 101 (8), 1134–1150. https://doi.org/10.1037/apl0000110/.

De Reyck, B., Y. Grushka-Cockayne, M. Lockett, S. R. Calderini, M. Moura, and A. Sloper. 2005. "The impact of project portfolio management on information technology projects." *Int. J. Project Manage.*, 23 (7), 524–537. https://doi.org/10.1016/j.ijproman.2005.02.003/.

DeLaurentis, D. A. 2005. "A taxonomy-based perspective for systems of systems design methods." In *Proc., 2005 IEEE International Conference on Systems, Man and Cybernetics*, 86–91. New York, NY: IEEE.

DeLaurentis, D. A. 2008. "Appropriate modeling and analysis for systems of systems: Case study synopses using a taxonomy." In *Proc., 2008 IEEE International Conference on System of Systems Engineering*, 1–6. New York, NY: IEEE.

DeLaurentis, D. A., and S. Ayyalasomayajula. 2009. "Exploring the synergy between industrial ecology and system of systems to understand complexity: A case study in air transportation." *J. Ind. Ecol.*, 13 (2), 247–263. https://doi.org/10.1111/j.1530-9290.2009.00121.x/.

Deloitte Center for Energy Solutions. 2015. *Deloitte Oil & Gas: Elevating the success of oil and gas capital projects*. Houston, TX: Deloitte Development. https://www2.deloitte.com/content/dam/Deloitte/us/Documents/energy-resources/us-er-oil-and-gas-capital-projects-service-offerings-04292015.pdf/.

Demmel, J. G., and R. G. Askin. 1992. "A multiple-objective decision model for the evaluation of advanced manufacturing system technologies." *J. Manuf. Syst.*, 11 (3), 179–194. https://doi.org/10.1016/0278-6125(92)90004-Y/.

Dionne, G. 2013. "Risk management: History, definition, and critique." *Risk Management and Insurance Review*, 16 (2), 147–166. https://doi.org/10.1111/rmir.12016/.

Elonen, S., and K. A. Artto. 2003. "Problems in managing internal development projects in multi-project environments." *Int. J. Project Manage.*, 21 (6), 395–402. https://doi.org/10.1016/S0263-7863(02)00097-2/.

Engwall, M. 2012. "PERT, Polaris, and the realities of project execution." *International Journal of Managing Projects in Business*, 5 (4), 595–616. https://doi.org/10.1108/17538371211268898/.

EY. 2014. *Spotlight on oil and gas megaprojects*. Houston, TX: EYGM Limited.

Floricel, S., and M. Ibanescu. 2008. "Using R&D portfolio management to deal with dynamic risk." *R&D Management*, 38 (5), 452–467. https://doi.org/10.1111/j.1467-9310.2008.00535.x/.

Flyvbjerg, B., M. Garbuio, and D. Lovallo. 2009. "Delusion and deception in large infrastructure projects: Two models for explaining and preventing executive disaster." *California Management Review*, 51 (2), 170–194. https://doi.org/10.2307/41166485/.

Ford, R. C., and W. A. Randolph. 1992. "Cross-functional structures: A review and integration of matrix organization and project management." *Journal of Management*, 18 (2), 267–294. https://doi.org/10.1177/014920639201800204/.

Foxon, T. J., R. Gross, A. Chase, J. Howes, A. Arnall, and D. Anderson. 2005. "UK innovation systems for new and renewable energy technologies: Drivers, barriers and systems failures." *Energy Policy*, 33 (16), 2123–2137. https://doi.org/10.1016/j.enpol.2004.04.011/.

Freeman, L. C. 1978–1979. "Centrality in social networks conceptual clarification." *Social Networks*, 1 (3), 215–239. https://doi.org/10.1016/0378-8733(78)90021-7/.

Ganegoda, D. B., and P. Bordia. 2019. "I can be happy for you, but not all the time: A contingency model of envy and positive empathy in the workplace." *Journal of Applied Psychology*, 104 (6), 776–795. https://doi.org/10.1037/apl0000377/.

Gardiner, P. D., and J. E. L. Simmons. 1992. "Analysis of conflict and change in construction projects." *Construction Management and Economics*, 10 (6), 459. https://doi.org/10.1080/01446199200000046/.

Govan, P. 2014. *Causal network methods for integrated project portfolio risk analysis* (PhD dissertation). College Station, TX: Texas A&M University.

Haidar, T. 2014. "4 out of every 5 oil & gas megaprojects fail. But why?" *The Boardroom* (podcast). https://www.oilandgasiq.com/oil-and-gas-production-and-operations/articles/the-boardroom-4-out-of-every-5-oil-gas-megaproject/.

Haji-Kazemi, S., B. Andersen, and O. J. Klakegg. 2015. "Barriers against effective responses to early warning signs in projects." *Int. J. Project Manage.*, 33 (5), 1068–1083. https://doi.org/10.1016/j.ijproman.2015.01.002/.

Haji-Kazemi, S., B. Andersen, H. P. Krane. 2013. "A review on possible approaches for dectecting early warning signs in projects." *Project Management Journal*, 44 (5), 55–69. https://doi.org/10.1002/pmj.21360/.

Hardesty, L. 2010. "Explained: Linear and nonlinear systems." *MIT News*, February 26, 2010. http://news.mit.edu/2010/explained-linear-0226/.

Hartman, F. T. 2000. “The role of TRUST in project management.” In *Proc., PMI Research Conference 2000*. Newtown Square, PA: Project Management Institute.

Hillson, D. 2003. "Using a risk breakdown structure in project management." *Journal of Facilities Management*, 2 (1), 85–97. https://doi.org/10.1108/14725960410808131/.

Hillson, D. 2006. *Using risk metalanguage to develop risk responses*. Hampshire, UK: Risk Doctor. https://www.praxisframework.org/files/hillson-22-cre-for%20risk-responses.pdf/.

Hillson, D. 2014. "Managing overall project risk." In *Proc., PMI Global Congress 2014.* Newton Square, PA: Project Management Institute.

Hillson, D., S. Grimaldi, and C. Rafele. 2006. "Managing project risks using a cross risk breakdown matrix." *Risk Management*, 8, 61–76. https://doi.org/10.1057/palgrave.rm.8250004

Hofman, M., S. Spalek, and G. Grela. 2017. "Shedding new light on project portfolio risk management." *Sustainability (2071-1050)*, 9 (10), 1798. https://doi.org/10.3390/su9101798/.

Huys, R., and V. K. Jirsa. 2011. *Nonlinear dynamics in human behavior*. Berlin, Germany: Springer-Verlag.

IEEE (Institute of Electrical and Electronics Engineers). 1990. *IEEE Standard Glossary of Software Engineering Terminology*. IEEE Standard 610.12-1990. New York, NY: IEEE.

Isabella, L. A. 1992. "Managing the challenges of trigger events: The mindsets governing adaptation to change." *Business Horizons*, 35 (5), 59–66. https://doi.org/10.1016/0007-6813(92)90055-E/.

Jonas, D. 2010. "Empowering project portfolio managers: How management involvement impacts project portfolio management performance." *Int. J. Project Manage.*, 28 (8), 818–831. https://doi.org/10.1016/j.ijproman.2010.07.002/.

Jonas, D., A. Kock, and H. G. Gemünden. 2013. "Predicting project portfolio success by measuring management quality—A longitudinal study." *IEEE Trans. Eng. Manage.*, 60 (2), 215–226. https://doi.org/10.1109/TEM.2012.2200041

Kerzner, H. 2009. *Project management: A systems approach to planning, scheduling, and controlling* (10th ed). Hoboken, NJ: John Wiley & Sons.

Klakegg, O. J., T. Williams, D. H. T. Walker, B. Andersen, and O. M. Magnussen. 2011. "Identifying and acting on early warning signs in complex projects." In *Proc., PMI Global Congress 2011*. Newton Square, PA: Project Management Institute.

Klir, G. J. 1972. *Trends in general systems theory*. New York, NY: Wiley-Interscience.

Kraaijenbrink, J. 2019. "Strategy in a complex world." *Forbes.* https://www.forbes.com/sites/jeroenkraaijenbrink/2019/02/05/strategy-in-a-complex-world/#30db18e01e39

Kyriakidis, M., V. Kant, S. Amir, and V. N. Dang. 2018. "Understanding human performance in sociotechnical systems – Steps towards a generic framework." *Saf. Sci.*, 107, 202–215. https://doi.org/10.1016/j.ssci.2017.07.008/.

Lencioni, P. 2007. *The five dysfunctions of a team: Participant workbook.* San Francisco, CA: Pfeiffer.

Lev, B. 2001. *Intangibles: Management, measurement, and reporting.* Washington, DC: The Brookings Institution.

Leveson, N. G. 2017. "Rasmussen's legacy: A paradigm change in engineering for safety." *Applied Ergonomics*, 59 (B), 581–591. https://doi.org/10.1016/j.apergo.2016.01.015/.

Levin, G., and J. Wyzalek. 2015. *Portfolio management: A strategic approach.* Boca Raton, FL: CRC Press.

Li, Y., Y. Lu., D. Li, and L. Ma. 2015. "Metanetwork analysis for project task assignment." *J. Constr. Eng. Manage.*, 141 (12): 4015044. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001019/.

Liew, Z. (n.d.). "Project management: Why projects fail.*" Project Smart.* www.projectsmart.co.uk/project-management-why-projects-fail.php/.

Long, J. C., F. C. Cunningham, and J. Braithwaite. 2013. "Bridges, brokers and boundary spanners in collaborative networks: A systematic review." *BMC Health Services Research*, 13: 158. https://doi.org/10.1186/1472-6963-13-158

Macal, C. M., and M. J. North. 2010. "Tutorial on agent-based modelling and simulation." *Journal of Simulation*, 4, 151–162. https://doi.org/10.1057/jos.2010.3/.

Maier, M. W. 1998. "Architecting principles for systems-of-systems." *Syst. Eng.*, 1 (4), 267–284.

Markowitz, H. M. 1959. *Portfolio selection: Efficient diversification of investments*. New Haven, CT: Yale University Press.

McCulloh, I. A., and K. M. Carley. 2008. *Social network change detectio*n. Pittsburgh, PA: Carnegie Mellon University. http://www.casos.cs.cmu.edu/publications/papers/CMU-CS-08-116.pdf

Merrill, J., S. Bakken, M. L. Rockoff, K. Gebbie, and K. M. Carley. 2007. "Description of a method to support public health information management: Organizational network analysis." *J. Biomed. Inf.*, 40 (4), 422–428. https://doi.org/10.1016/j.jbi.2006.09.004/.

Min, J. H., W. Jang, S. H. Han, D. Kim, and Y. H. Kwak. 2018. "How conflict occurs and what causes conflict: Conflict analysis framework for public infrastructure projects." *J. Manage. Eng.*, 34 (4): 04018019. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000625/.

Morris, R. A. 2008. "Stop the insanity of failing projects." *Industrial Management*, 50 (6), 20–24.

Morton, S. C., A. R. J. Dainty, N. D. Burns, N. J. Brookes, and C. J. Backhouse. 2006. "Managing relationships to improve performance: A case study in the global aerospace industry." *Int. J. Prod. Res.*, 44 (16), 3227–3241. https://doi.org/10.1080/00207540600577809/.

Muiño, A., and F. Akselrad. 2009. "Gates to success: Ensuring the quality of the planning." In *Proc., PMI Global Congress 2009.* Newton Square, PA: Project Management Institute.

National Aeronatuics and Space Administration. 2010. "The 21st century space shuttle." https://spaceflight.nasa.gov/shuttle/upgrades/upgrades5.html/.

National Research Council. 2003. *Dynamic social network modeling and analysis: Workshop summary and papers.* Washington, DC: National Academies Press.

Nichita, E.-M. 2019. "Intangible assets – insights from a literature review." *Accounting and Management Information Systems*, 18 (2), 224–261. http://dx.doi.org/10.24818/jamis.2019.02004/.

Nikander, I. O., and E. Eloranta. 2001. "Project management by early warnings." *Int. J. Project Manage.*, 19 (7), 385–399. https://doi.org/10.1016/S0263-7863(00)00021-1/.

Nogeste, K., and D. H. T. Walker. 2005. "Project outcomes and outputs: Making the intangible tangible." *Measuring Business Excellence*, 9 (4), 55–68. https://doi.org/10.1108/13683040510634844/.

Nogeste, K., and H. T. W. Derek. 2008. "Development of a method to improve the definition and alignment of intangible project outcomes and tangible project outputs." *International Journal of Managing Projects in Business*, 1 (2), 279–287. https://doi.org/10.1108/17538370810866377/.

O'Donnell, D., P. O'Regan, B. Coates, T. Kennedy, B. Keary, and G. Berkery. 2003. "Human interaction: The critical source of intangible value." *Journal of Intellectual Capital*, 4 (1), 82–99. https://doi.org/10.1108/14691930310455405/.

O'Hare, D. 2000. "The 'Wheel of Misfortune': A taxonomic approach to human factors in accident investigation and analysis in aviation and other complex systems." *Ergonomics*, 43 (12), 2001–2019. https://doi.org/10.1080/00140130050201445/.

Oil & Gas Authority. 2017. *Lessons learned from UKCS oil and gas projects 2011-2016*. London, UK: Oil and Gas Authority. https://www.ogauthority.co.uk/media/3380/oga-lessons-learned-from-ukcs-oil-and-gas-projects-2011-2016.pdf/.

Olsson, R. 2008. "Risk management in a multi-project environment – An approach to manage portfolio risks." *International Journal of Quality & Reliability Management*, 25 (1), 60–71. https://doi.org/10.1108/02656710810843586/.

Osei-Kyei, R., A. P. C. Chan, Y. Yu, C. Chen, and A. Dansoh. 2019. "Root causes of conflict and conflict resolution mechanisms in public-private partnerships: Comparative study between Ghana and China." *Cities*, 87, 185–195. https://doi.org/10.1016/j.cities.2018.10.001/.

Peck, W., and B. Casey. 2011. "Accountability without authority: How to drive employees crazy." *Wendi and Bill's Blog* (Executive Leadership Group blog). https://pronto-core-cdn.prontomarketing.com/82/wp-content/uploads/2011/04/Accountability-without-Authority-How-to-Drive-Employees-Crazy.pdf/.

Pellegrinelli, S. 1997. "Programme management: Organising project-based change." *Int. J. Project Manage.*, 15 (3), 141–149. https://doi.org/10.1016/S0263-7863(96)00063-4/.

Project Management Institute. 2013. *The standard for portfolio management* (3rd ed). Newton Square, PA: Project Management Institute.

Project Management Institute. 2017. *A guide to the project management body of knowledge* (6th ed.). Newton Square, PA: Project Management Institute.

Rasmussen, J. 1997. "Risk management in a dynamic society: A modelling problem." *Saf. Sci.*, 27 (2–3), 183–213. https://doi.org/10.1016/S0925-7535(97)00052-0/.

Rasool, M., T. Franck, B. Denys, and N. Halidou. 2012. "Methodology and tools for risk evaluation in construction projects using Risk Breakdown Structure." *European Journal of Environmental and Civil Engineering*, 16 (sup1), s78–s98. https://doi.org/10.1080/19648189.2012.681959/.

Repenning, N. P., and J. D. Sterman. 2001. "Nobody ever gets credit for fixing problems that never happened: Creating and sustaining process improvement." *California Management Review*, 43 (4), 64–88. https://doi.org/10.2307/41166101/.

Rodrigues, A. G. 2001. "Managing and modelling project risk dynamics: A systems dynamics-based framework." In *Proc., 4th European PMI Conference*, London, England: Project Management Institute.

Rodrigues, F. A. 2019. "Network centrality: An introduction." In E. E. N. Macau (Ed.), *A mathematical modeling approach from nonlinear dynamics to complex systems*, 177–196. Cham, Switzerland: Springer International Publishing.

Rolstadås, A., I. Tommelein, P. M. Schiefloe, and G. Ballard. 2014. "Understanding project success through analysis of project management approach." *International Journal of Managing Projects in Business*, 7 (4), 638–660. https://doi.org/10.1108/IJMPB-09-2013-0048/.

Roth, G. L. and P. M. Senge. 1996. "From theory to practice: Research territory, processes and structure at an organizational learning centre." *Journal of Organizational Change Management*, 9 (1), 92–106. https://doi.org/10.1108/09534819610107349/.

Rousseau, V., C. Aubé, and A. Savoie. 2006. "Teamwork behaviors: A review and an integration of frameworks." *Small Group Research*, 37 (5), 540–570. https://doi.org/10.1177/1046496406293125/.

Sage, A. P., and C. D. Cuppan. 2001. "On the systems engineering and management of systems of systems and federations of systems." *Information-Knowledge-Systems Management*, 2 (4), 325–345.

Salapatas, J. N. 2000. "Best practices--The nine elements to success." In *Proc., Project Management Institute Annual Seminars & Symposium*. Newton Square, PA: Project Management Institute.

Salas, E., M. L. Shuffler, A. L. Thayer, W. L. Bedwell, and E. H. Lazzara. 2015. "Understanding and improving teamwork in organizations: A scientifically based practical guide." *Human Resource Management*, 54 (4), 599–622. https://doi.org/10.1002/hrm.21628/.

Sanchez, H., B. Robert, M. Bourgault., and R. Pellerin. 2009. "Risk management applied to projects, programs, and portfolios." *International Journal of Managing Projects in Business*, 2(1), 14–35. https://doi.org/10.1108/17538370910930491/.

Saunders, A., and E. Brynjolfsson. 2016. "Valuing information technology related intangible assets." *MIS Quarterly*, 40 (1), 83–110. https://doi.org/10.25300/MISQ/2016/40.1.04/.

Sauser, B. 2009. "How the experts quantify sports: From identifying raw talent to measuring team chemistry, experts discuss the statistical side of sports." *MIT Technology Review*, March 9, 2009. https://www.technologyreview.com/2009/03/09/215008/how-the-experts-quantify-sports-2/.

Schloss, E. P. 2014. "A dynamic framework for planning under simple, complicated, and complex conditions." *Emergence: Complexity and Organization*, 16 (2), 93–106.

Schroeder, B., and J. A. Jackson. 2007. "Why Traditional Risk Management Fails in the Oil and Gas Sector: Empirical Front-Line Evidence and Effective Solutions." *AACE International Transactions*, 01.01–01.06.

Skitmore, R. M., S. G. Stradling, and A. P. Tuohy. 1989. "Project management under uncertainty." *Construction Management & Economics*, 7 (2), 103.

Skorupka, D. 2004. "Neural networks in the risk management of a project." In *2004 AACE International Transactions*. Morgantown, WV: AACE International.

Skyttner, L. 2006. *General systems theory: Problems, perspectives, practice* (2nd ed.). Singapore: World Scientific Publishing Co.

Sterman, J. (2000). *Business dynamics: Systems thinking and modeling for a complex world*. New York, NY: McGraw-Hill.

Symonds, M. (2011). 15 causes of project failure. *Project Smart*, June 13, 2011. www.projectsmart.co.uk/15-causes-of-project-failure.php/.

Tah, J. H. M., and V. Carr. 2001. "Knowledge-based approach to construction project risk management." *J. Comput. Civ. Eng.*, 15 (3), 170–177. https://doi.org/10.1061/(ASCE)0887-3801(2001)15:3(170)/.

Tartell, R. 2017. "Who does what? Use RACI to figure it out!" *Training*, 54 (4), 12.

Teller, J., and A. Kock. 2013. "An empirical investigation on how portfolio risk management influences project portfolio success." *Int. J. Project Manage.*, 31 (6), 817–829. https://doi.org/10.1016/j.ijproman.2012.11.012/.

Teller, J., A. Kock, and H. G. Gemünden. 2014. "Risk management in project portfolios is more than managing project risks: A contingency perspective on risk management." *Project Management Journal*, 45 (4), 67–80. https://doi.org/10.1002/pmj.21431/.

Thamhaim, H. J., and D. L. Wilemon. 1975. "Conflict management in project life cycles." *Sloan Management Review*, 16 (3), 31–50.

Uher, T. E., and A. R. Toakley. 1999. "Risk management in the conceptual phase of a project." *Int. J. Project Manage.*, 17 (3), 161–169. https://doi.org/10.1016/S0263-7863(98)00024-6/.

Varro, L. 2018. *World energy investment 2018*. Paris, France: IEA.

Walther, J., S. E. Miller, and N. W. Sochacka. 2017. "A model of empathy in engineering as a core skill, practice orientation, and professional way of being." *J. Eng. Educ.*, 106 (1), 123–148. https://doi.org/10.1002/jee.20159/.

Wang, T., S. Gao, X. Li, and X. Ning. 2018. "A meta-network-based risk evaluation and control method for industrialized building construction projects." *J. Cleaner Prod.*, 205, 552–564. https://doi.org/10.1016/j.jclepro.2018.09.127/.

Ward, S. C., and C. B. Chapman. 1995. "Risk-management perspective on the project lifecycle." *Int. J. Project Manage.*, 13 (3), 145–149. https://doi.org/10.1016/0263-7863(95)00008-E/.

William, T. E., and Č. Rūta. 2017. "The relationship between dynamic capabilities and project portfolio risk management: Theoretical framework." In *Proc., 6th International Scientific Conference on Project Management in the Baltic Countries*, 293–308. Riga, Latvia: University of Latvia.

Yin, R. K. 2014. *Case study research: Design and methods* (5th ed.). Thousand Oaks, CA: SAGE Publications.

Yuan, J., K. Chen, W. Li, C. Ji, Z. Wang, and M. J. Skibniewski. 2018. "Social network analysis for social risks of construction projects in high-density urban areas in China." *J. Cleaner Prod.*, 198, 940–961. https://doi.org/10.1016/j.jclepro.2018.07.109/.

Zhang, G., and P. X. Zou. 2007. "Fuzzy analytical hierarchy process risk assessment approach for joint venture construction projects in China." *J. Constr. Eng. Manage.*, 133 (10), 771–779. https://doi.org/10.1061/(ASCE)0733-9364(2007)133:10(771)/.

Zhu, J. 2016. *A system-of-systems framework for assessment of resilience in complex construction projects* (PhD dissertation). Miami, FL: Florida International University.

Zhu, J., and A. Mostafavi. 2014. "A system-of-systems framework for performance assessment in complex construction projects." *Organization, Technology and Management in Construction*, 6 (3), 1083–1093. https://doi.org/10.5592/otmcj.2014.3.2/.

Zhu, J., and A. Mostafavi. 2017. "Discovering complexity and emergent properties in project systems: A new approach to understanding project performance." *Int. J. Project Manage.*, 35 (1), 1–12. https://doi.org/10.1016/j.ijproman.2016.10.004