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A Structured Project-Risk Management and Life Cycle Framework for Complex Systems: Ship Repair and Maintenance (SR&M) Projects

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A STRUCTURED PROJECT-RISK MANAGEMENT AND LIFE CYCLE FRAMEWORK FOR COMPLEX SYSTEMS: SHIP REPAIR AND MAINTENANCE (SR&M) PROJECTS

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ABSTRACT

A STRUCTURED PROJECT-RISK MANAGENMENT AND LIFE CYCLE FRAMEWORK FOR COMPLEX SYSTEMS: SHIP REPAIR AND MAINTENANCE (SR&M) PROJECTS

Michael Craig Plumb
Old Dominion University, 2010
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This dissertation contributes to insights regarding the implications of using Project Risk Management (PRM) and Life Cycle Assessment (LCA) in managing projects for a complex system. The PRM approach apprehends many forms of risk both internal and external within a given project and assists the manager in determining the level of importance of each individual project phase and component to optimize project success. The life cycle approach to project management is used with short-term limitations with respect to a product's life cycle over several years. The literature discusses many tools and techniques that assist project managers in implementing optimal solutions, but published statistics indicate failures to meet schedules and/or budgets are still common. This dissertation combines PRM and LCA for ship repair and maintenance projects for a ship's 35-year service life. A framework highlighting the fundamentals of PRM and LCA was developed for the purpose of improving a ship's service life and operability.

The results of the analysis of survey data from subject matter experts indicate that a PRM and LCA of complex systems is a viable methodology. The framework was validated by subject matter experts and produced viable evidence that the proposed

framework, if implemented, may have a 34% success rate of accomplishing its stated purpose of: reducing ship systems, equipment, or component failure rates; reducing a ship's life-time costs; and improve ship reliability towards meeting its 35 year operational service life.

Furthermore, this dissertation contributes to the body of knowledge in the fields of project-risk management and life cycle applications by providing a framework of a complex system of systems of ship repair and maintenance that can be used for any complex system of organizational entities.

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INTRODUCTION

1.1 Purpose of the Study

1.1.1 Ship Repair and Maintenance (SR&M) Background

The inspection, repair, and maintenance of ships (vessels) in the United States Navy are an exceedingly expensive and complex system of interrelated operations with time-sensitive mission imperatives. The rapid growth of complex systems on naval vessels, coupled with extensive interoperability requirements, make each vessel a "system of systems" connected with various parts of other ships, shore-based command and other organizational systems. The Naval Sea Systems Command is comprised of command staff, headquarters directorates, affiliated Program Executive Offices (PEOs) and numerous field activities. The function of their engineers and managers is to build, buy and maintain ships, submarines and their combat systems to meet current and future Fleet operational requirements. Naval Sea Systems Command (NAVSEA) is the largest of the Navy's five system commands, and for fiscal years 2009 – 2012 projections are for $30 billion according to the NAVSEA Strategic Business Plan, 2008. "Service life is a key variable in future force planning regardless of any other variable considered." (Koenig, Nalchajian, & Hootman, 2008, p.1) NAVSEA Division 21 is the organizational group focused on specific classes of ship maintenance requirements to ensure operational readiness. This group currently partners with the Type Commander to determine scheduling of ship inspections, repairs, and maintenance to be accomplished during availability periods.

The employment of vessel program and project managers falls under the purview of Fleet Commanders, Type Commander who oversee large, geographically dispersed, and complex shipbuilding, repair, and maintenance projects on surface and subsurface vessels, each with unique systems, idiosyncrasies, and mission requirements. The U.S. Navy has created a new command to better manage surface ships by type or class. In 2006, the Navy created "class squadrons," also known as CLASSRON to assist NAVSEA 21 to "better" manage surface ship inspections, repairs, and maintenance projects. The CLASSRONs were established with the specific purpose of coordinating the support of ships by class/type, wherever they may be home ported. This organization and function has been absorbed by the Type Commander as of 2011.

In 2009, the Navy created another organization to manage the scheduling of surface ship inspections, repairs, and maintenance projects. The command is called "SSLCM" which stands for Surface Ship Life Cycle Management Activity. The organization is directed to establish a sustainable, repeatable, disciplined, and predictive maintenance planning, execution, and budgeting process that delivers the right maintenance resources at the right time and cost for the life cycle (service life) of a surface ship. SSLCM's impact on ship repair and maintenance impact on service life has yet to be realized. As of 2011, the SSLCM has been again renamed the Surface Maintenance Engineering Planning Program (SURFMEPP) Activity.

The Navy has had two general approaches to addressing budget limitations, which are vessel design or architecture and fleet structure or optimizing the mix of vessels for mission readiness. Fleet size was last updated on May 20, 2008 with a Ship Battle Force of 313 ships and submarines. (O'Rourke, 2008) Current budget allocations limit the programmed numbers of new vessels to be built, and cost savings derived from fleet modernization, repair, and maintenance funding can be diverted to new ship construction. A more optimal alternative is to extend the service life of vessels, regardless of ramifications and other unknown variables. But, “relatively small changes in service life projections or assumptions have direct and large impacts on future force structure.” (Koenig, et al., 2008. p. 1) “Navy planners can be sorted under two top-level headings: (1) alternative concepts for future force structures, ship designs, and acquisition strategies; and (2) alternative projections of ship service life, which are (a) synthesis and analysis of future naval fleets, (b) views of service life, and (c) service life impact on force structure and elements that impact actual ship service life.” (Koenig, et al., 2008, p. 1) Lower level decisions are based upon individual and vessel class problems experienced by operational fleet units. “Operational service life accounts for the differential rate of ship aging between operational years and years out of commission.” (Koenig, et al., 2008, p. 4)

The fleet commanders demand on having their fleet units ready for deployment at a specified time for a multitude of missions. Ship readiness is the watch word to enable forces to be deployed to troubled countries or geographical areas around the globe. To date, “the Navy has not conducted a comprehensive study of a ship design to determine the relationship between cost-to-design-and-build and the years of intended service.” (Koenig, et al., 2008, p. 5). There are many perceptions regarding shipbuilding and researchers have studied repair and maintenance from different perspectives. This study focuses on increasing a vessel’s service life by applying a life-cycle perspective for surface ship inspection, repair, and maintenance work package from a Project Risk Management and Life Cycle assessment perspective.

1.1.2 SR&M Industry Importance

The mission of Naval Sea Systems Command (NAVSEA) is to develop, deliver and maintain ships and systems on time and within budget for the United States Navy, and to meet operational commitments for the defense of the United States of America and her allies. The importance of this industry is not only economic, but critical to national security. There must be a viable, sustained industrial expertise in shipbuilding, repair, and maintenance, and the assurance of maintaining secrecy in the many processes, equipment, and methods used to construct highly complex and advanced weapon's platforms of the United States Navy.

The NAVSEA's purpose is the execution of directives and fulfillment of Mission imperatives to enable the Navy to carry out the defense of the United States of America. To accomplish this endeavor, NAVSEA manages 150 acquisition programs and manages foreign military sales cases that include billions of dollars in annual military sales to partner nations. The NAVSEA organization has 33 activities in 16 states, with a force of 45,000 civilian, military and contract support personnel, in 310 occupations. NAVSEA engineers, builds, buys and maintains the Navy's ships and submarines and their combat systems. (Hynes et al., 2002, p. 1)

NAVSEA has the further responsibility of establishing and enforcing technical authority in ship systems design and operation. The organization's technical expertise uses these technical standards to ensure ship systems are engineered efficiently and effectively, and operate safely and reliably. The importance of the shipbuilding, repair, and maintenance industry is critical to the defense of the United States. Within each ship class, all ships are scheduled and expected to have the same service life, and that predetermined number is used to plan the Shipbuilding & Conversion budget, and the "Operations and Maintenance – Navy (OM&N) budget, manpower needs, and other items within the Future Year Defense Plan (FYDP). It is also used to project future force structure beyond the FYDP as reported to Congress in the 30 Year Shipbuilding Plan." (Koenig, et al., 2008, p. 4)

1.1.3 Current trends in SR&M

The Navy is studying the future of operational commitments and projected fleet capabilities required for as yet unknown enemy and/or potential enemy capabilities and political goals. As the tempo of operations increase due to international pressures and tensions, the President, as Commander-in-Chief, may require the Navy to perform additional duties and deploy naval vessels for new missions. Additionally, budget limitations imposed by Congress may limit or restrict the Navy in numbers of ships, which may force tradeoffs to be made between repair and maintenance and shipbuilding funds. One example is cost savings realized from reallocating new ship construction funding to current ship repair and maintenance budgets, by extending the service life of ships from 30 years to 35 years. The intent is to utilize some of the new ship construction funds to maintain and upgrade ship system capabilities for five additional years. This cost saving method is to increase the service life of current ships in the fleet. As a result, the savings realized in delaying new ships' construction is expended after additional system upgrades, repairs and maintenance is spent on older vessels. The current trend is to increase ship service life. "A general, long-term movement to increase service life implies that vessel maintenance will assume greater relative importance and will incur increased costs." (Koenig, et al., 2008. p. 8) The elements influencing a ship's service life are: (1) technical obsolescence of its integrated warfare systems and components; and (2) maintenance during a ship's service life. Theoretically, a "carefully maintained vessels can serve out their entire expected service life. But inadequate maintenance during the early and middle ranges of a ship's life can make the life extension prohibitively expensive and this in the absence of other overriding factors, would prompt a decision to retire early." (Koenig, et al., 2008, p. 8)

The current trend of NAVSEA's efforts to reduce costs, maximize resources, and improve efficiencies in the shipbuilding, repair, and maintenance of vessels remains in the management of systems of systems engineering, with respect to decision making utilizing multi-objective tradeoff analyses in maximizing project costs by vessel class at best. The project management aspect of shipbuilding, repair, and maintenance of any naval vessel may appear simple, but is actually quite complex when one looks at the many systems and interrelated sub-systems that must be maintained in top condition. Additionally, the project manager must also consider the vessel's role in the squadron, cruiser-destroyer group, and fleet of naval vessels, all "competing" for funding, adjusting schedules and deployment rotations, and delaying much needed work that is performed by fewer and fewer shipyards and maintenance facilities. This may appear as a project manager's nightmare, but according to a Rand study, "we found that the most common concerns of defense analysts were cost, schedule, industrial base capacity, shipyard performance, and program management strategies." (Arena, Schank, & Abbott, 2004, p. XV) Further, "we found that existing tools lacked an integrated approach that would allow analysts to consider not just individual elements (e. g., manpower and procurement funding requirements) but the interaction and interrelationships among the industrial base components – from attrition rates to ship-life extensions, from labor-learning curves to overhead costs." (Arena, et al., 2004, XV)

One area not under close scrutiny is the risk and life cycle impact of complex systems in making the proper decisions based on their impact on a ship's 35 year service life. The system and/or program managers look upon "risk" for components of systems and the "risk" of system failure as it affects mission accomplishment parameters. It should also be noted that the Navy is directed to attain a 30-year naval force sized to be 319 ships which are to be attained by year 2020. This exceeds the current (2008) force size of 287 vessels. The Navy's perspective in shipbuilding, specifically the naval vessel construction risk, is based upon, "... the Department of the Navy (DoN) new ship construction procurement and funding plans for FY 2009 and the Future Years Defense Plan (FYDP) as reflected in the FY 2009 President's Budget submission." (OPNAV N8F, 2008, p. 6)

The complex project management environment of ship inspections, repairs and maintenance, compounded with decreasing budgets, cause current studies to focus on ways to manage SR&M risk and life cycle assessment perspective towards reducing current and future budgetary or cost factors to preclude, figuratively speaking, "the perfect storm" of having to do more with less. To deflect or reduce the pending budget shortfalls, the application of a decision management and decision analysis procedure to a complex project management scenario may assist.

Decision management has become an important discipline, due to an increasing need of automated systems to aid managers in making decisions across organizations to provide the decision-making process with precision, consistency, and agility by providing up-to-date information. The Navy uses several metrics for measuring inspection, repair, and maintenance availability periods as being either a success or a failure, in making the ship "mission ready." The three primary considerations are cost, ship schedule, quality of work performed, and compliance with procedural (repair and/or maintenance) requirements. There are many methods of improving readiness, whether on paper or in reality, by making tradeoffs between cost and schedule, weighing the cost of inspections, repairs or maintenance for now versus later, as well as considering shore resources and yards, and fleet budgetary considerations.

Managers from many commands and organizations make these decisions based on their perspectives and metrics to reduce costs in the short term and enable a ship to keep its operational schedule, thus providing "THE" overall metric of success in how well their organization is managing its budgeted resources. Navy program and project managers are dealing with increasingly complex ship systems, and face ever increasing pressure for optimal ship inspection, repair, and maintenance availabilities based upon short-term decisions for a ship operating cycle of 18 months. The life cycle view of these short-term successes in ship operations may prove to be detrimental to the long-term service life and total ship cost. Enter Decision Analysis.

Decision analysis comprises the philosophy, theory, methodology, and practice necessary to address important decisions in a formal manner. The term was coined by Professor Ronald A. Howard at Stanford University in 1964 and is responsible for developing much of the decision analysis practice and professional applications. Parnell et al (2008) use the system life cycle. Figure 1 (adapted from Parnell, 2008, p. 56) indicates the NAVSEA Vessel Decision Process applied to vessel system whole-life cycle, from inception to removal from service and disposal. This research focuses on the operational service life of the vessel, determined to be 35 years.

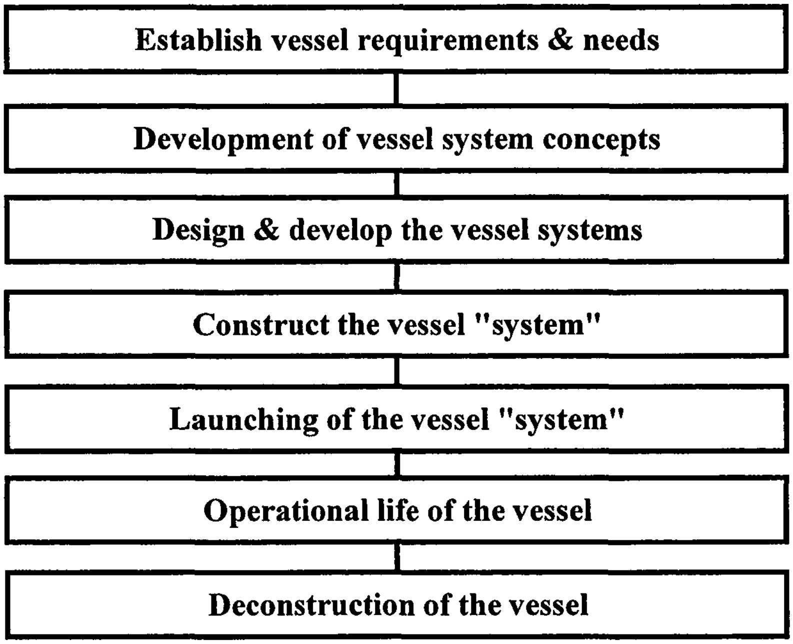


Figure 1: NAVSEA Vessel Decision Process.
Adapted from Parnell et al (2008). *Decision Making in Systems Engineering and Management.*

1.1.4 Brief Description of Systems Science

Systems science, as applied to project management, risk management, decision management, and life-cycle management comprise the areas of theoretical foundation for this research. The formal definitions associated with systems science are essential in understanding the relationship between systems theory, systems thinking, and systems practice and their relationship to project management, risk management, decision-making process, and life cycle. The definitions provided in Appendix A provide needed terminology to ensure guidance and focus in this research on the issues addressed.

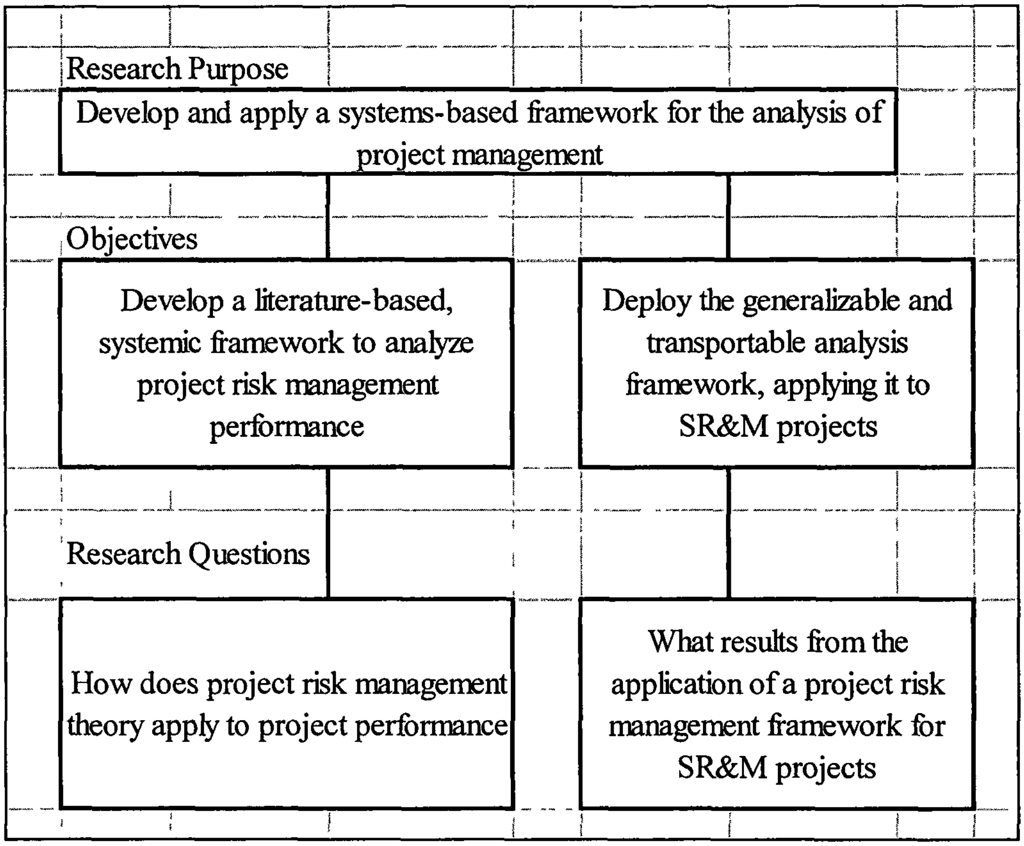


Figure 2: Systems Science, Origin and Evolution
Adapted from Flood & Carson (1993). *Dealing with Complexity: An Introduction to the Theory and Application of Systems Science.* (2nd ed.).

Figure 2 indicates how systems principles are the foundation for systems theory, which in turn promotes systems thinking, which can be used in systems practice to improve the effectiveness in project management development in project risk management.

1.1.5 Research Approach to SR&M

The preceding definitions are essential elements in understanding the relationship between science and project risk management, and decision and life cycle management. One should note that the systems principles of scientific hierarchy include laws, principles, theorems, hypotheses, and axioms associated with systems, and consequently the underlying areas of project management, risk management, decision management, and life-cycle applications. One may logically point out that these principles form the body of theory relating to the study of systems. Boulding (1956) categorizes them as: "… a body of systematic theoretical constructs with general relationships in the empirical world." (Boulding, 1956, p. 197) Skyttner (1998) states that, "to a certain extent, systemic knowledge must be considered produced, not discovered. (Skyttner, 1998, p. 202)

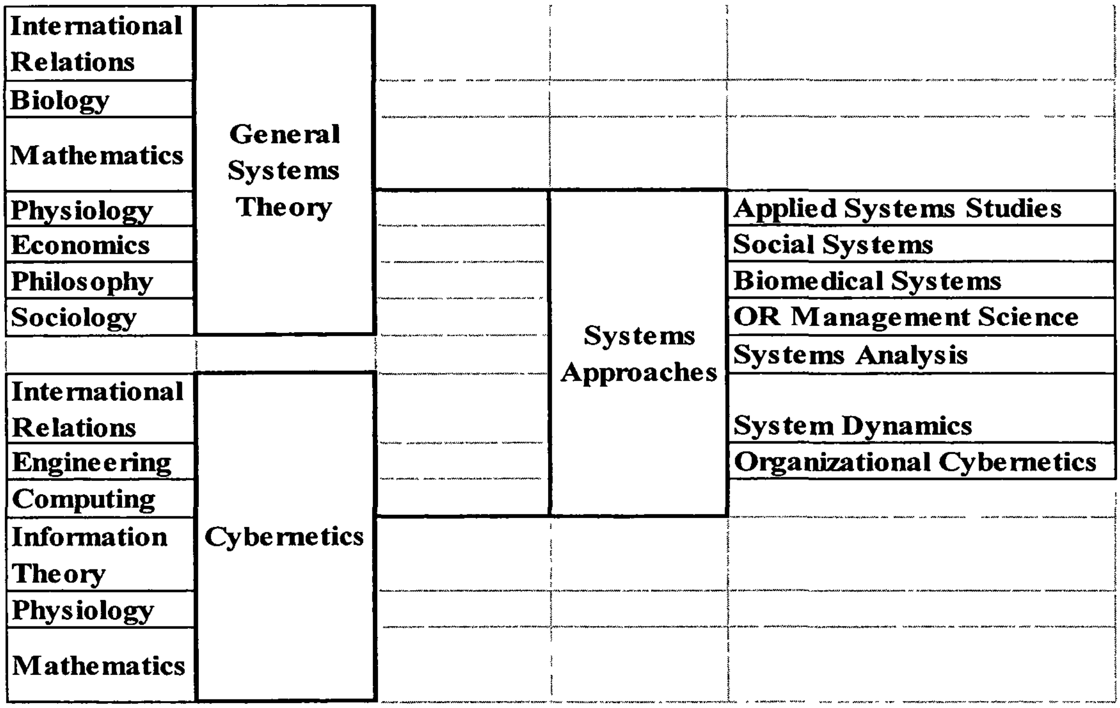


Figure 3: Structure of the Inquiry
Adapted from Miles & Huberman (1994). *Qualitative Data Analysis.* (2nd ed.)

Figure 3 served to guide the research. The model or framework's importance is derived from its ability to relate systems principles both to the goal of research development and to the application of a project risk management framework for the optimization of complex system projects and the analysis of its performance. Additional value was derived from the model's ability to depict the generalizability of the research goal to project management and the larger field of systems engineering.

The overall structure for the inquiry in ship repair and maintenance (SR&M) from a life-cycle approach is outlined in Figure 4 below.

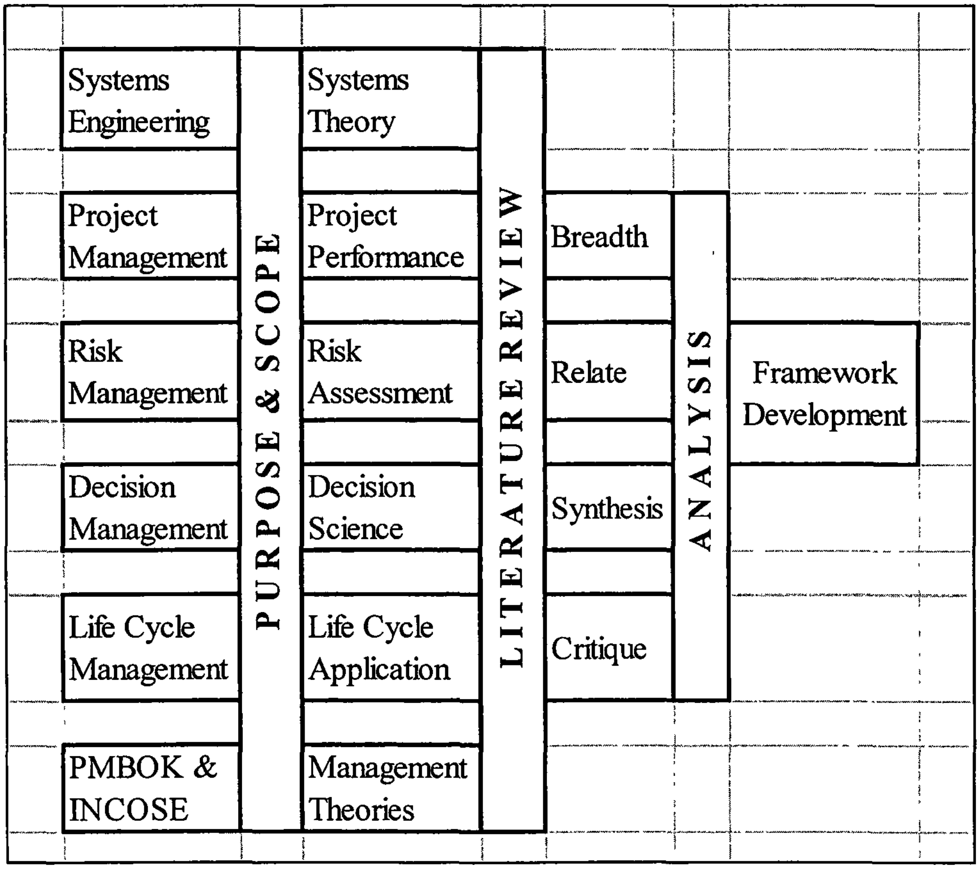


Figure 4: Literature Review Schema
Adapted from Creswell (1994) Research Design: Qualitative & Quantitative Approaches.

1.2 Research Question

The application of a structured framework for ship, risk-management, life-cycle assessment development may provide insight into optimizing the decision management process of naval ship inspections, repairs, and maintenance. Although the navy is currently able to meet mission imperatives, future contingencies may require further reductions in resources with expanding theaters of operational commitments. To address this, the purpose of this research is designed with two elements. The first element is to build on the existing foundation of systems engineering and project management theory by focusing on the following research question:

How can systems engineering theory apply to the analysis of project-risk and life cycle management performance for ship repair and maintenance?

The research used the case study method to develop a theoretical framework for risk management and life cycle development. The framework is literature-based and developed using expert opinion through a case study and survey method for triangulation. The framework is a conceptual model that may be applied to complex management scenarios to enhance system performance. The framework is not a detailed step-by-step methodology, but will provide as an outline for the articulation of engineering management processes using project risk management theory with life-cycle assessment. The overall goal is to provide a general, transferable framework for the optimization of engineering management within the project management body of knowledge. The strength of the framework is to establish theoretical constructs derived from the project management-theory body of knowledge.

The validation will use real world project management decision making currently employed by the Navy. The scientific basis for the case study generalization is differentiated from the experimental generalization where data is generalized to larger samples and/or populations. The case study approach used a method of generalization called analytic generalization, in which "…the investigator is striving to generalize a particular set of results to some broader theory." (Yin, 2003, p. 37) Analytic generalization is the generalizing of a theory, or framework and is based on validating framework "driven" predictions with evidence collected in a variety of real world vessel class settings from case study research. Analytic generalization may reveal contextual conditions under which the framework based predictions would be considered to apply, serving to increase confidence (substantiated by triangulation) in the theory as illustrated in the framework. This element of research is centered on analysis of the empirical data from the case study, triangulated with expert judgment questionnaires and interviews, in comparison with the descriptive theory presented in the framework. The validation will use real world project management decision makers currently employed by the Department of the Navy1.3 Research Objectives

1.3 Research Objectives

Supporting the purpose of the research are two focused objectives. The objectives are:

- Develop the literature based, case study framework applying project risk management and life cycle assessment to SR&M scheduling.
- Develop the literature based, case study framework applying project risk management and life cycle assessment that is generalizable to any complex system.

The framework was developed using case study research of existing laws, rules, edicts, directives, and a plethora of programs and instructions from governmental sources. See Appendix B. The existing literature provided a basis of current operations and needs of the U. S. Navy. These needs are better utilization of current budgets for SR&M while meeting mission and operational commitments.

1.4 Research Significance

As will be further elaborated in the next chapter, the literature has established that a major gap exists in recent research on project risk management and life cycle assessment of complex systems. Neglecting this approach precludes an understanding of the overall system, where systems engineering and project risk management may permit a better understanding of the overall and management process.

This research makes five significant contributions to engineering management, systems engineering, and project management and to the VCRM practice:

- First, it adds to the existing body of knowledge in project management, systems based methods, and decision management by developing an extensible framework, grounded in case study and survey triangulation, for evaluating project risk management in a complex system environment of VCRM, where a life cycle approach is not utilized.

- Secondly, it expands the domain of project management methodologies by providing a systems-based framework for the assessment and evaluation of complex engineering projects as part of optimizing a vessel project risk management performance improvement process.

- Thirdly, the research makes a significant contribution to project risk management practitioners who, as part of their discipline, now have a general and transportable framework that can be utilized in assessing and evaluating project performance.

- Fourthly, this research provides areas for future research that include the conduct of additional case studies and/or an expanded use of the framework.

- Lastly, this research contributes to the body of knowledge on qualitative research.

1.5 Study Limitations

This section addresses three research limitations required to ensure that the study maintained the proper research focus and accomplishment of the research purpose. The limitations to the research were: (a) the use of a qualitative element using expert opinion, to build a framework; (b) the use of a quantitative element where an objective approach and case study methodology were used to validate the utility of the framework on real-world project management systems; and (c) the ability to generalize from a case study. All three limitations will be explored in detail.

The common challenge to utilizing expert opinion is through the use of expert sampling, which involves assembling a sample of persons with known and/or demonstrable experience and expertise in the area. The limitations are the small sample of experts. It is understandable that there may be issues in subject matter experts between their expertise and knowledge and (Navy) policies. However, "using expert sampling is the best way to elicit the views of persons who have the specific expertise." (Trochim & Donnelly, 2007, p. 49) In this case, expert sampling is "the best way to elicit the views of persons who have specific expertise." (Trochim & Donnelly, 2007, p. 50) The other reason to "use expert sampling is to provide evidence for the validity of another sampling approach." (Trochim & Donnelly, 2007, p. 50) Essentially just a specific sub-case of purposive sampling and "you sample with a purpose in mind." (Trochim & Donnelly, 2007) The other reason to use expert sampling is, "...to provide evidence for the validity of another sampling approach.." (Trochim & Donnelly, 2007) The disadvantage is that "even the experts can be, and are often, wrong. (Trochim & Donnelly, 2007, p. 50)

The use of a quantitative element in a case study methodology is not being used to validate the utility of the framework in this real-world complex system project management scenario. "Some qualitative researchers reject the framework of validity that is commonly accepted in more quantitative research in the social sciences. They reject the idea that there is a single reality that exists separate from our perceptions. In their view, each of us sees a different reality because we see it from a different perspective and through different experiences. They don't think research can be judged using the criteria of validity. Research is less about getting at the truth than it is about researching meaningful conclusions." (Trochim & Donnelly, 2007, p. 148) This method is further precluded due to the sensitivity of ship inspections, repairs, and maintenance scheduling, and especially the availability material and system outcomes.

The ability to generalize from a case study "...refers to the degree to which the results of quantitative research can be generalized or transferred to other context or settings. From a qualitative perspective, transferability is primarily the responsibility of the one doing the generalizing. The qualitative researcher can enhance transferability by doing a thorough job of describing the research context and the assumptions that were central to the research. The person who wishes to transfer the results to a different context is then responsible for making the judgment of how sensible the transfer is." (Trochim & Donnelly, 2007, p. 149) Moreover, the case study method has been considered to be very weak as a research methodology based on claims that the method does not have sufficient precision or quantification, objectivity, or the needed rigor. Methods of this validation may include credibility, dependability, and conformability. Credibility involves establishing that the results of the qualitative research are credible from the perspective of the researcher. "The idea of dependability, on the other hand, emphasizes the need for the researcher to account for the ever-changing context within which research occurs." (Trochim & Donnelly, 2007, p. 149) "Confirmability refers the degree to which others can confirm or corroborate the results." (Trochim & Donnelly, 2007, p. 149) The three prejudices against case study research, according to Yin (2003) are: (1) the concern over the lack of rigor; (2) that they provide little basis for scientific generalization; and (3) is that they take too long and result in massive, unreadable documents. The natural science model invokes construct validity, internal validity, external validity, and reliability as measures of design quality. (Yin, 2003, p. 10-11) These measures added significant relevance to this element of the research.

In summary, the case study method research design was selected in direct response to the research questions in Figure 3: Structure of the Inquiry. It should be noted at this point that no single method could adequately address each of the questions, so the case study was based upon a qualitative (subjective) approach and was determined to best meet the research goals. This method approach provided the research with significant strengths and limitations associated with the ontological assumptions associated with this method. The limitations associated with this method were identified and accounted for previously.

1.6 Study Delimitations

This section discusses four delimitations of the research. The research did not consider every ship class in the U. S. Navy, nor those of the U. S. Army, U. S. Coast Guard, nor commercial vessels, but a subset of those project management processes where holistic, systems-based principles may be applied as a part of an overall framework for improvement. As such, the focus of the research was not on how the Navy performs project management for SR&M, nor how to improve the current system or sub-system, but on the overall development process or system domain, applying a project risk management life cycle framework to the current system domain.

The research did a case study of project-risk management and life-cycle assessment processes and procedures from the perspective of the U. S. Navy, and not from all applicable domains. In order to accurately describe the complex system of SR&M of the Navy's many classes of specialized vessels, the selection included relevant categories that were mutually exclusive, exhaustive, and comparable. (Gerring, 2001) The selection criteria were: (1) all project types whether accomplished by a governmental entity, a commercial company, or a combination of both; (2) project duration where the project had a beginning and an ending date; (3) project budget, and whether the project came in under budget, on budget, or over budget; and (4) project completion quality of work. The research included projects from all classes of vessels. Budgetary and quality of work issues were neglected for this dissertation area of research.

1.7 Summary

This chapter described how the study developed and applied a systems-based framework for the analysis of project risk management project performance. It has shown how the detailed research questions and higher level objectives support the purpose and fit within the structure of the overall inquiry. It has presented systems science as the theoretical foundation for the research and shown how systems principles, theory, and practice relate to project risk management life cycle in project management and engineering management. The chapter highlights the significance of the four areas of the research to both the body of knowledge and the practice of project risk management. It has identified boundaries for the study and a discussion of the limitations and delimitations.

A key challenge will be the relatively brief duration of this project management research methodology. In this and many instances, engineering management procedures and processes have been or may be changed or completely reorganized within the short span of this research and will moreover will be experienced within a ship or ship class service life. By introducing research purpose, objectives, and questions, the chapter provides a smooth transition to the following chapter. The next chapter frames the research setting within the literature and addresses how the research relates systems principles and project risk management to project performance. Significant import will be given to the schema for the literature review, the breadth of the study, and gaps in the literature.

CHAPTER 2

LITERATURE REVIEW

This chapter establishes the setting for the dissertation research, frames it appropriately within the literature and addresses how the research relates systems principles to project risk management, and the development of project management. The chapter presents the rationale and approach underlying the review, including the search schema and breadth of the literature review. A detailed critique of the literature in each of the four focus areas was conducted and a concise report of the findings and themes presented. The final section summarizes the gaps in the research.

2.1 Rationale and Approach

The focus of the literature review was to reduce the volume of information presented in the scholarly journals to that which was relevant and necessary for the research area. Trochim & Donnelly (2007) indicated that the schema and breadth of the literature review must ensure that the researcher is exposed to an appropriate "range of ideas, concepts, and theories, which must identify related research to ensure the current dissertation research areas are within conceptual and theoretical contexts. Booth et al (2003) indicates that the boundary of the research must include the researcher establishing himself in a field where rules aren't fully understandable or practicable, including the subtle and unspoken rules that present themselves, including the customs and practices of complex organizations. Another boundary consideration was the researcher's conceptual view of the world from experience, training, and education. This personal boundary acted as a filter affecting the observations made by this researcher, in deciding to include or exclude specific journal articles and published manuscripts in the literature review.

The task was to ensure that underlying assumptions and boundaries of the literature review were made explicit. This has added significance because the outputs in the early stage of the research were factual. The schema for and the scholarly journals included in the literature review were explicitly stated, however, "the rationale used to discriminate journal articles and published manuscripts for triangulation was problematic and required explicit guidelines that addressed their inclusion or exclusion of their notes, similarities and differences, as pointed out by Dyer (1979)."(Sproull, 1995, p. 105). In this case study, the focus is to describe how systems theory may be applied to project risk management with life cycle application in the analysis of project management performance? The explicit rationale for inclusion or exclusion of journal articles and published manuscripts were from the synthesized literature review per Guba & Lincoln (1994) to ensure that the results include all facts that were theory-laden and/or value-laden. The following guidelines were used to ensure explicit guidance:

- The researcher rigorously reviewed the articles, journals, and governmental documents, searching for articles on: (a) systems engineering; (b) project risk management development; (c) life cycle management; and (d) decision management.
- Journal articles from topical areas (a) through (d) were evaluated against the conception how does systems engineering apply to the analysis of project risk management performance.

- The researcher used his academic knowledge and training in engineering management and thirty years in government and industry to ensure that journal articles and published manuscripts provide the quality and empirical rigor to warrant selection and inclusion in the synthesized literature review.

Finally, prior to the actual framework validation, an expert review was conducted to verify that the information synthesized in the literature review was sufficient and appropriate. The use of an expert, outside the researcher, was intended to decrease research risk by ensuring that the information selected by the researcher was sufficient to provide a firm foundation for modeling a project risk management framework.

2.2 Literature Search Schema

The multi-disciplinary nature of project management required the inclusion of a variety of scholarly literature from the systems engineering, project management, risk management, life cycle management, and decision management fields of study. The literature search within these was focused in the areas:

- Systems engineering principles
- Project risk management development
- Life cycle management
- Decision management.

The Figure 4 Literature Schema depicts the schema for the literature review and how the wide body of knowledge was narrowed to support the development of a generalizable evaluation for a framework for project risk management development. The purpose and scope was drawn from systems engineering, project management, risk management, decision management, life cycle management including the PMI's Project Management Body of Knowledge (PMBOK) and the International Council of Systems Engineering (INCOSE) Systems Engineering Handbook, A Guide for System Life Cycle Processes and Activities. This was further solidified during the literature review to reduce and focus the breadth of the research materials, relating specific literature to the narrow subject area, synthesizing pertinent literature, in supporting the development of the proposed framework through a careful analysis and critique.

2.3 Breadth of Review

The literature search included appropriate scholarly journals in the fields associated with the research purpose and primary research questions. A clear distinction was made between published literature founded on empirical research and that published with no empirical basis, with the latter included as referenced government documents, instructions, and publications. As stated, the sources included in the schema were from a wide variety of disciplines and scholarly journals as noted in Appendix B: Literature Review List.

The scholarly journals selected for the literature review were included to describe the theoretical perspectives and previous research findings related to the research purpose. Appendix B includes the primary scholarly journals in systems engineering, engineering management, project management, decision management, risk management, life cycle management, and governmental directives, manuals, and instructions. Journal articles related to the research purpose were classified into four areas: (a) systems engineering principles; (b) project risk management development; (c) life cycle management; and (d) decision management (project risk management performance). A scholarly review and a concise report of the findings and themes present in the literature were conducted. The synthesis of the literature in each of the four primary threads of the research purpose is presented in the following sections.

2.3 1 Initial Literature Search

There are many levels of management and oversight impacting decisions regarding ship repair and maintenance. See Figure 5: Systems Managers vice Project Managers.

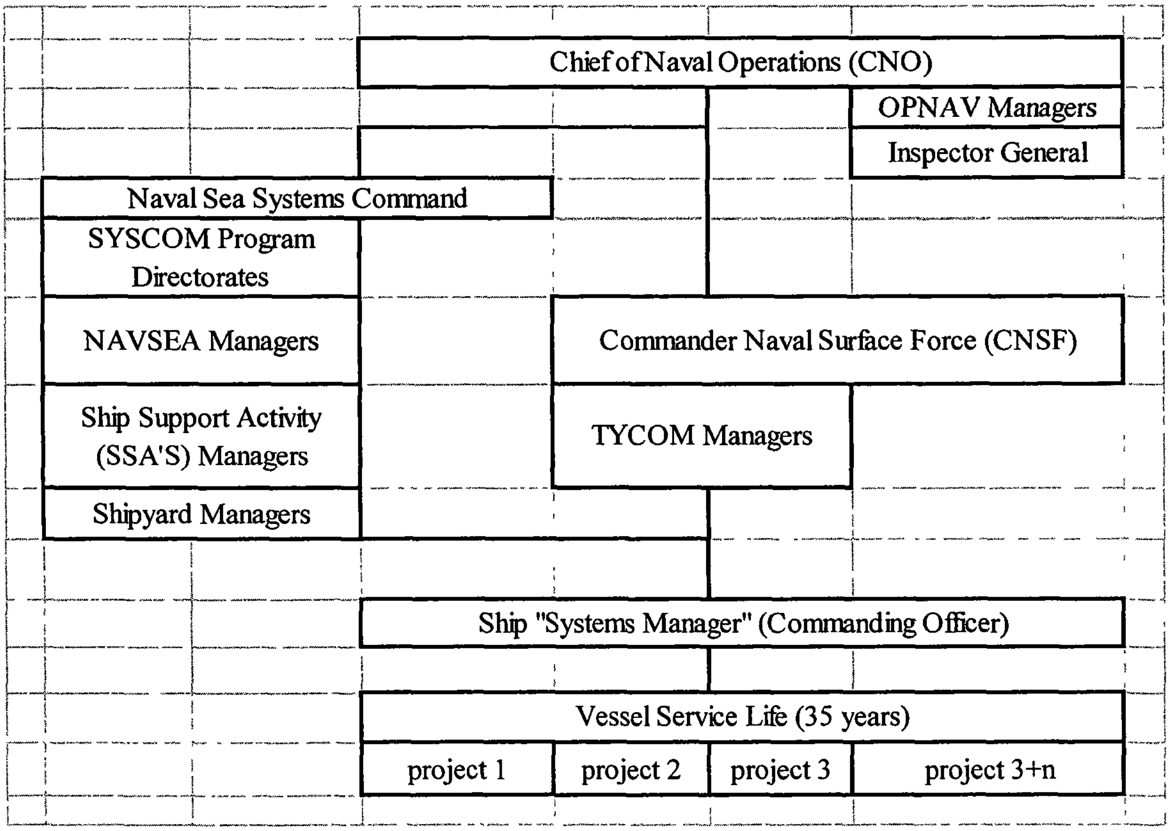


Figure 5: Systems Managers vs. Project Managers

The many directors, program managers, and the lower level project managers have very narrow and specific areas of purview on meeting command functions and goals. The higher in the command structure, such as SECNAV and CNO, the more directive in nature, to meet of organizational purpose(s) and goal(s). NAVSEA is directed to deal with ship material readiness, from inception, design, construction, repair and maintenance, and retirement from service. CNSF on the other hand, is responsible to ensure ships meet their operational commitments in all respects to include material and systems readiness. Ship Support Activities, such as Norfolk Ship Support Activity, is tasked to manage the work projects for a ship's availability period through a Port Engineer. The ship's Commanding Officer is the overall manager with the specific focus on completing the availability on time and fully operational. These aforementioned perspectives may at times appear to be at odds in completing a ship's availability timeline and budget. The purpose of the research is to develop and apply a systems-based-framework for the analysis of project risk management performance.

The many governmental directives, studies, programs, instructions, procedures, methods, and tools for identifying, representing, and formal assessments of what SR&M projects to accept and which decisions to assess as a success, may appear confusing to an outsider to the Navy. There are many levels of management and oversight, from many points-of-view, such as operational, budgetary, political, and resource limited facilities, and parts and material priority allocations and needs.

In reviewing governmental documents from various branches, agencies, and departments, there is little mention of practicing a project risk management using a life cycle assessment for selecting inspection and work items for a ship's availability. Further, the navy's management focus is on budgetary costs, ship schedule, as well as in procedural compliance of repairs and maintenance. Additional directives and lower level instructions differ to the point that they may be interpreted being at variance or juxtaposition with each other. One point to note is the absence of life cycle management guidance in terms of the engineering management perspective of a ship's service life. The Navy perspective focuses on a ship's 18 month operational cycle, excluding future inspections and work items held in abeyance for a future availability after a forward deployment.

Graphical representation of decision analysis problems may use various methods, such as influence diagrams or decision trees. These tools are two alternatives for the decision maker, the uncertainty faced, and the evaluation methodology selected to achieve project related objectives or goals. Uncertainties represented through probabilities and probability distributions, from a life cycle perspective, do not appear in written instructions by navy managers, either from a short term or long term perspective. The fleet commander's focus is on ship service life whereas shore commands focus on resources and time lines. The decision maker's attitude to risk is represented by utility functions and their attitude to trade-offs between conflicting objectives can be made using multi-attribute value functions or multi-attribute utility functions, if risk is deemed to exist. These utility functions can be replaced by the probability of achieving uncertain aspiration levels.

Decision analysis basically makes the decision based on the consequences of the maximum expected utility, or to maximize the probability of achieving an uncertain outcome. Kien (2003) voices the growing concern that these tools do not lead to making improved decision making. He further points out that the approach is prescriptive, and provides a prescription of what actions to take based on “sound logic,” rather than a descriptive approach that describes flaws in the way people make decisions. Cook (2007) describes changing the view of decision making from "a separate process to being a facet of work and ....the paramount importance of time that the three assumptions ... are no longer tenable. (Cook, 2006, p. 6)

(1) Complete information cannot be upheld because the environment is dynamic rather than static.

(2) Infinite sensitivity is untenable for the same reason as above, namely that it would require time to differentiate among alternatives.

(3) Weak ordering must be abandoned because people normally do not have time to consider all alternatives they have found, even if it is not the complete set.

Furthermore, according to Taylor & Raden (2007), several studies conclusively show how even the simplest decision analysis methods are superior to "unaided intuition."

The literature search was expanded to the following areas: engineering management and decision making; project risk management; production management; systems engineering; operational service life; risk and uncertainty; to include: project cost overruns, project delivery date failures; and industry specific problems to vessel construction, repair, and maintenance. This study includes case studies and interviews, with hypothetical examples predominately related to ship availability completion and system operability, prior to a ship’s scheduled operational deployment.

Literature regarding Systems Engineering, Engineering Management, Knowledge Management, Project Management, Risk Management, Life Cycle, and governmental directives, instructions, papers, and presentations, and other areas were reviewed in order to determine the current state of SR&M industry, and to identify the links and gaps between project risk management and life cycle approaches in the field of management and engineering management. Specific articles, laws, directives, instructions, journal articles, textbooks, and other sources are listed with respective areas of specification and delineation may be found in Appendix B: Literature Review List. The most obvious trend is the lack of interest and action to include risk assessment in lower level instructions and directives as well as any semblance of a life cycle view or consideration in ship repair and maintenance, to enable ship's to reach their 35-year service life meeting mission requirements.

2.3.2 Literature Review

In describing the area of risk management from a Ship Repair and Maintenance (SR&M) perspective, one finds the same risks as in other fields of industry and business. The risks within each project are: (1) schedule changes (planned & unplanned); (2) performance; (3) environmental conditions; (4) cost; (5) safety; and (6) security (present in all companies to varying degrees). Haimes (2004) indicates that to be effective and meaningful, risk assessment and management must be an integral part of the overall management of a system. He adds that it is particularly important in the management of highly technological and complex systems, where the failure of the system can be caused by failure of hardware, software, organizational procedures as designed or as practiced by the "humans involved."

Risk assessment is the first step in the risk management process, with the goal being either determining a qualitative or quantitative metric that may be applied to recognize a risk related threat to project objectives and/or completion. Risk perception is the subjective judgment that people make about the characteristics and severity of a risk. One phrase commonly used in reference to natural hazards and threats to the environment or health, such as nuclear power. Estimates of risk vary, and different risk managers may provide different estimates as to the severity of a certain risk. Once there has been a verifiable risk concern, the next step is to perform a risk analysis of the perceived risk to the project. Risk analysis is considered the "science of risks," their probability of occurrence, and the evaluation of their potential for occurrence and the ramification to the project. The purpose of the research is to develop and apply a systems-based-framework for the analysis of project risk management performance.

2.4 Synthesis of the Literature of Project Management Principles

Systems engineering was the initial thread in the literature review. Project management is the second and primary thread, as managed by systems engineering management oversight. The previous Figure 2: Literature Review Schema is provided to orient the reader during the extensive literature review. The development of systems "science" has been developed over the last several decades, with various emphases and purposes. From Beishon (1976), to Flood and Carson (1993), and Hammond (2003), it has been shown how systems approaches have evolved into distinct areas. To understand and use systems-based principles, one may need to look further.

Checkland (1999), in his text *Systems Thinking, Systems Practice*, includes a 30-year retrospective and includes techniques for building conceptual models, based on simple principles which have been tested in many systems studies over several years. Flood and Carson (1993) indicate that systems science arises from interdisciplinary studies in the experimental sciences. Peter Checkland as one of the applied systems science major practitioners states that when one thinks about any system, one must "... make conscious use of the particular concept of wholeness captured in the word system as a means to order our thoughts." (Checkland, 1993, p. 4) This perspective is well founded and exemplifies many systems thinkers. Figure 2: Systems Science Origin and Evolution depicts the aforementioned interrelationships.

2.4 1 Systems Engineering

Systems engineering may best be generally described as an interdisciplinary field of engineering that focuses on how complex engineering projects should be designed and managed. The issues of logistics, the coordination of different teams, and automatic control of machinery become much more difficult when dealing with large and complex organizational projects. Systems engineering primarily focuses on the processes and tools to manage such projects, and it overlaps with both technical and human-centered disciplines, such as control engineering and project management. Systems engineering tools are strategies, procedures, and techniques that aid in performing systems engineering on a project or product. The purpose of these tools vary from database management, graphical browsing, simulation, document production, and more

There are many definitions of what a system is in the field of systems engineering. Below are a few authoritative definitions:

- ANSI/EIA-632-1999: "An aggregation of end products and enabling products to achieve a given purpose."

- IEEE Std 1220-1998: "A set or arrangement of elements and processes that are related and whose behavior satisfies customer/operational needs and provides for life cycle sustainment of the products."
- ISO/IEC 15288 states "A combination of interacting elements organized to achieve one or more stated purposes." (INCOSE SE Handbook, 2006, p. 3.3)
- NASA Systems Engineering Handbook: "(1) The combination of elements that function together to produce the capability to meet a need. The elements include all hardware, software, equipment, facilities, personnel, processes, and procedures needed for this purpose. (2) The end product (which performs operational functions) and enabling products (which provide life-cycle support services to the operational end products) that make up a system."□
- INCOSE (2006) Systems Engineering Handbook, states: "...homogeneous entity that exhibits predefined behavior in the real world and is composed of heterogeneous parts that do not individually exhibit that behavior and an integrated configuration of components and/or subsystems.
- INCOSE (2006) Systems Engineering Handbook, states: "A system is a construct or collection of different elements that together produce results not obtainable by the elements alone. The elements, or parts, can include people, hardware, software, facilities, policies, and documents; that is, all things required to produce systems-level results. The results include system level qualities, properties, characteristics, functions, behavior and performance. The value added by the system as a whole, beyond that contributed independently by the parts, is

> primarily created by the relationship among the parts; that is, how they are interconnected."

International Council on Systems Engineering (INCOSE) defines systems engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem. Areas of concern are operations, cost and scheduling, performance, testing, training and support, manufacturing, and disposal. INCOSE delineates systems engineering further as integrating all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.

Systems processes, defined from a "systems engineering" perspective, is also an approach and a discipline within engineering management. The systems engineering focus is to formalize the approach and in doing so, identify new methods and research opportunities similar to the way it occurs in other fields of engineering. As an approach, systems engineering is holistic and interdisciplinary in flavor.

The definition of systems engineering has evolved also, and include terms such as complex, customers, stakeholders, and others. Today's systems engineers include their customers, both internal and external, and all stakeholders in addressing the multitude of contextual situations of real world engineering contextual problems, from problem identification through the solution process. Complex systems require a holistic and systemic understanding of the technical problem and the solution from a contextual framework. This framework is the focus of this study and research.

For Systems Manager versus Project (Risk) Manager, the "gap" in the literature is that project managers (e.g. Commanding Officers) are concerned with project risks as their only view in the current system (e.g. ship condition and its ability to perform mission essential deployments).

The Project Managers may also be concerned with immediate project risks as well, their interest in long range system performance (e.g. vessel or vessel class material readiness towards vessel viability during its projected service life). There is also a "gap" in project management in that there are always political as well as budgetary issues at odds with technical issues of any project, competing for corporate and/or departmental funds or resources.

2.4.2 Complexity

Complexity is present in every system. Flood (1990) provides a paradigmatic interpretation relating complexity and systems. There are three ways to relate system and complexity according to Flood. (Flood and Carson, 1993, p. 34):

(1) Systems are real and tangible things. They are groups of elements related to the whole. Boundaries are easy to identify. Complexity is often measured in terms of the number of elements, and the number of relationships and attributes of these such as linearity, symmetry, and nonholonomic constraints. Complexity and system are therefore synonymous in a real sense. System is prime.

(2) Systems are real but are difficult to access and know. Their reality is known through interpretations. Complexity and systems are not synonymous because people factors such as interpretation muddle system identification. Neither system nor people are prime.

(3) The realness and existence of systems is questioned. "Systems" are people's actions and the social rules and practices that define those actions. Systems therefore are contingent on there being people. Take away the people and systems do not exist. Complexity and system have no clear relationship other than system being a structure through which we organize our thoughts about the world. People are prime." The project management community can benefit from the above theory in gaining insight and understanding of the system driving their projects. To summarize, complexity is present in every engineering endeavor, project management being no exception.

2.4.3 Project Management

In defining project management, one must first define: What is a project? "A project is an endeavor that has a definable objective, consumes resources, and operates under a time, cost, and quality constraints." (Kerzner, 2004, p. 1) Project management may also be defined as "the planning, scheduling, and controlling of a series of integrated tasks such as the objectives of the project are achieved successfully and in the best interest of the project stakeholders." (Kerzner, 2004, p. 2) "A project is a sequence of unique, complex, and connected activities having one goal or purpose, and that must be completed by a specific time, within budget, and according to specification." (Wysocki, 2007, p. 34) "Kerzner (2005) defined a project as a series of activities and tasks that (1) have a specific objective to be completed within a certain performance specification (e.g., time, quality, schedule), (2) have limited resources (e.g., time, personnel), (3) have defined start and end dates, (4) have a project manager and a project team with the authority and responsibility over the accomplishment of the project objectives, and (5) have knowledge needs." (Landaeta, 2008, p. 30)

A textbook definition of project management may be defined as, "... the planning, scheduling, and controlling of a series of integrated tasks such as the objectives of the project are achieved successfully and in the best interest of the project stakeholders." (Kerzner, 2004, p.2) He further indicates, that a project may also be described as "a multifunctional activity, Additionally, Kerzner indicates that a "multifunctional activity" that must also possess direction, a specific outcome, and a defined goal. A generally accepted description of a project is " a sequence of unique, complex, and connected activities having one goal or purpose and that must be completed by a specific time, within budget, and according to specifications." (Wysocki, 2007, p. 4) As most often the case in managing any complex of highly technological project, unanticipated disruptions and delays caused by planned or unplanned schedule changes; performance issues; environmental conditions; cost; safety; and security issues that will impact the project life cycle activity sequences and inevitably impacting project budget and scheduled completion.

Project activities may be considered complex or numerous activities that are connected by fit, form, function, and sequenced to attain the desired outcome or goal. It is understood generally that projects must have a single goal and a specified completion date." (Wysocki, 2007) (Kerzner, 2005) Many projects of complex systems such as ship repair and maintenance are also interconnected by competitive and limited resources.

Lastly, Wysocki indicated that a project completion date may be "self-imposed by management or externally specified by a customer or government agency." (Wysocki, 2007, p. 5)

In the author's thirty-plus years in the U. S. Navy, commercial merchant marine, and the shipbuilding and repair industry, frequent, costly and common challenges have included managing projects that have been overrun by costs and schedule extensions which occurred on a frequent and costly basis. In 2004, industry statistics show that there were 56% cost overruns, with 18% failed projects, 53% challenged projects and only 28% successful projects. (Johnson, 2006, p. 1) These cost overrun numbers are shared by other industries such as aerospace (over 40%), construction (58%), and rolling stock (100%). (Williams, 2005, p. 499)

"Good management of technological systems must address the holistic nature of the system in terms of its hierarchical, organizational, and fundamental decisionmaking structure. Also to be considered are the multiple noncommensurate objectives, subobjectives, and sub-subobjectives, including all types of important and relevant risks, the various horizons, the multiple decision makers, constituencies, power brokers, stakeholders, and the users of the system, as well as a host of institutional legal, and other socioeconomic conditions." (Haimes, 2004, p. 18)

The most common challenges are resource allocation and time. Projects have resource limitations such as manpower, machinery or facilities, and money budgeted for the duration of the specified timeline. These variables require constant evaluation and balancing to provide the optimal formula for project completion. Every project has a multitude of risks that can preclude its completion on time and within budget, delivering the specified product or service. From a vessel construction, repair, and maintenance life-cycle perspective, “Engineering systems are always designed, constructed, and operated under unavoidable conditions of risk and uncertainty and are often expected to achieve multiple and conflicting objectives.” (Haimes, 2004, p. 19) The project risk management aspect will be discussed later in this study.

The goals of project managers are to keep their project within the constraints of time or schedule, and within budget. When viewed through a vessel life cycle perspective, the individual project goals may be compromised in the near term, to produce savings not realized for the longer term of many years. It would be logical that a “long term program manager or project manager” would be more apt to best manage a vessel over its lifetime, but 30 plus years is longer than most careers, be they management or engineering. One note this author will make is that a project’s goal of time, budget, and quality are generally used to define a project’s success or failure. Perhaps this may be an area for further study of other parameters.

Risks are inherent in any complex system, and every “crisis” has different risk factors and impacts based upon doing nothing, or doing something. Every alternative to a solution has varying risk factors and consequential mitigating circumstances with varying risk factors and costs. In project management, it is usual risk management practice to identify two fundamental properties of risk events, likelihood and consequence. “Even with the most modern and up to date management techniques and tools, and risk prediction models, totally unexpected events will still occur in projects.” (Gillanders, 2007, p. 3) Further, in discussing risk, one must define what it actually may be, relative to management and management situations in the shipbuilding and repair industry.

Generally speaking, there are two perspectives relating to risk: one being the classical view where risks can be objectively measured; the second is the Bayesian view whereby risk is an expression of the degree of uncertainty.

Project risk is usually evaluated from the inception of and in defining the project. As often the case, some clients always seem to expect more than can be delivered. In other words, what specific and measureable deliverable will be completed and accepted by the customer? "The Conditions of Satisfaction (COS) statement provides the input you need to generate the Project Overview Statement (POS)." (Wysocki, 2007, p. 86) The POS is a short document, usually one page that concisely states what is to be accomplished in the project, why it is to be done, and the business value it will provide to the enterprise at completion. Wysocki (2007) indicates that the main purpose of the POS is to "secure senior management approval and the resources needed to develop a detailed project plan, which will be reviewed by the managers who are responsible for setting priorities and deciding what projects to support. Once approved, the POS becomes the foundation for future planning and execution of the project……and the reference document for questions or conflicts regarding the project scope and purpose." (Wysocki, 2007, p. 87)

Wysocki (2007) further indicates that a POS is composed of five parts: a problem or opportunity; a project goal; project objectives; criteria for success; and assumptions, risks, obstacles which are explained below:

- Part 1, problem/opportunity: "based upon FACT and should require neither further delineation nor defense as it has been mutually accepted by all parties. (Wysocki, 2007, p. 88)

- Part 2 project goal: states the goal of the project or what and how one intends to address the problem or opportunity specified in part 1. Doran (1981) indicated in an article that S.M.A.R.T. characteristics (Specific, Measurable, Achievable, Realistic, and Time-Bound) provide the criteria for a goal statement: specific, measurable, assignable, realistic, and time specific. "The project goal should provide purpose and direction to the project." (Wysocki, 2007, p. 90)
- Part 3, project objectives: clarify and define the boundaries of the goal statement and the project scope. "The objective statement should include the following: what is to be accomplished; the plan of action and milestones, success metrics, and how the objective(s) will be attained." (Wysocki, 2007, p. 92)
- Part 4, identifying success criteria: "...may include increased revenue, reduced costs, and improved service." (Wysocki, 2007, p. 93)
- Part 5, listing assumptions, risks, and obstacles: "Do not assume that everyone knows what the risks and perils to the project will be."(Wysocki, 2007, p. 95) "There are several areas where the project can be exposed to factors that may inhibit project success: technological, environmental, interpersonal, cultural, and causal relationships." (Wysocki, 2007, p. 97)

Risk analysis is more the rule as projects become more complex. Formal procedures include: identification of the risk factors; the likelihood of occurrence; their impact on the project and other operations; the likelihood of their occurrence; and their potential damage to project success. Lastly, a financial analysis will be conducted before granting approval to perform the detailed planning. Types of analyzes may include: feasibility studies; cost/benefit analysis; break-even analysis; and/or return on investment.

One challenge of this study is to educate project managers as to the use of risk assessment and management in determining the need for the periodic accomplishment of repair and/or maintenance project(s) regardless of all other factors for a vessel to attain its thirty-five (35) year service life. If periodic repair and maintenance projects are deferred until a later date, the ship systems may be subject to increased or compounded risk of system failure(s). The other aspect of risk management may be in identifying future technological improvements or advances, and how they may impact vessel construction, and specifically repair and maintenance projects. From this author's experience, electronics and combat systems change rapidly to meet perceived and future threats by naval forces.

The trends in addressing these challenges have not changed, even in the shipbuilding, repair, and maintenance of highly complex ship systems, and in spite of precise tracking methodologies and practices. The fact remains that projects habitually fail to finish on time, over budget, and/or do not meet project objectives or deliverables. Project "failures" remain a common occurrence in spite of improved programs and methodologies. According to Project Management Network Magazine, "failure causes per a January 2007 poll of 1,007 respondents indicate the following: 28% poor communication; 18% insufficient resource planning; 13.2 % unrealistic schedules; 9.8% poor project requirements; 6.7% lack of stakeholder buy-in; 5.2% undefined project success/closure criteria; 4.8% unrealistic budgets; 4.4% insufficient or no risk planning; and 4.3% lack of control of the change process." (PMI, 2007, p. 19) Additionally, according to Defense Industry Daily, from vessel construction, repair, and maintenance perspective, there are cost overruns, and uncertainty of future contract work for shipyards providing highly specialized, often classified or priority engineering methods or practices that may not otherwise be made available for non-government customers. ("Cost Overruns, Budget Uncertainties Hurting USN and Contractors," 2005, p. 1) For shipbuilders and commercial ship maintenance facilities, contracted company managers experience feast or famine in bidding for navy contracts, which makes hiring and keeping skilled workers difficult during lean periods of little or no contract work. The purpose of the research is to develop and apply a systems-based-framework for the analysis of project risk management performance.

2.5 Synthesis of the Literature of Risk Management Principles

2.5 1 Project Risk Management

When project managers encounter risks in their projects, what can they do? The obvious answer is they should make an attempt to manage it. “Risk is a major factor in the management of projects because of their one-time nature and the uniqueness of the deliverables.” (Shtub, 2005, p. 355) Young stated that “As a project manager, you have the obligation, working with your team, to: (1) identify and evaluate potential risks; (2) derive a response strategy and action plans to contain the risks; (3) implement the actions and monitor the results; and (4) promptly resolve any issues arising from risks that happen.” (Young, 2004, p. 110-111). Hornjak (2001) indicated that there are several methods to “handle” risky situations using a crisis management methodology, and which include: (1) belt-and-suspenders approach(i.e. have sufficient insurance to be immunized from problems); (2) pin-the-blame approach (i.e. blame someone else directly or indirectly involved); (3) the tombstone approach (which is to have total disregard for potentially disastrous consequences of inaction and do nothing); and (4) slash-and-burn approach (which involves outsiders waiting in the wings to "turn around" or dismember a company). (Hornjak, 2001, p. 4-5) There are considerations for risk assessment as well as management in systems engineering manuals, books, and journal articles, but little connectivity to project management. To date, this author has been unable to obtain a study or journal article (to date) that directly addresses "project risk management."

2.5.2 Risk Management

Project Risk Management does not equate to Project Management, as the application of risk assessment and the ability of understanding risk assessments is neglected in many instances and industries. Risk may be defined as a concept denoting a potential negative impact to a characteristic of value arising from a future event, occurrence, or a combination of events. Moreover, one can say that risks are events or conditions that may occur and whose occurrence, if it takes place, has a deleterious effect or impact on a project's schedule or budget. Moreover, a projects exposure to consequences of uncertainty constitutes risk in and of itself. In everyday usage, risk is used synonymously with the probability of a known loss. Risk is more often than not, defined as a measure of the probability and severity of adverse effects." (Lowrance, 1976, p. 94) (Haimes, 2004, p. 4)

Project risk management seeks to anticipate and address uncertainties that threaten the goals of a project. Risk analysis is risk management. Program managers and system engineers should monitor, measure, and mitigate risk throughout the system life cycle. (Parnell, Driscoll, & Henderson, 2008, p. 71) Further, "The premise that risk assessment and management must be an integral part of the overall decision-making process necessitates following a systematic, holistic approach to dealing with risk." (Haimes, 2004, p. 4) The International Council on Systems Engineering (INCOSE) recognizes four categories of risk that must be considered during a systems decision problem: (1) technical risk; (2) cost risk; (3) schedule risk; and (4) programmatic risk. (INCOSE, 2006, p. 5.9)

The importance of Vessel Life-Cycle Risk Management approach is to optimize the use of (Navy's) limited SR&M funding. One approach the Navy has implemented is extending the service life of vessels from 30 to 35 years, to meet an optimal fleet mix of mission capable vessels. (Koenig, 2008, p. 2) Paramount to all Navy Program Managers and Project Managers, are the following components of a vessel's life cycle: (1) vessel construction and delivery schedule; (2) meeting a vessel operational schedule; (3) vessel sailing with other than fully operational systems, and equipment, and armament; (4) vessel unable to perform mission essential functions; (5) operational equipment safety concerns; (6) vessel personnel safety issues; (7) vessel overhaul/repair/maintenance Plan of Action & Milestones; and (8) vessel decommissioning Plan of Action & Milestones.

Uncertainty invites an exposure to risk, which may cause project management failures such as over budget, exceeding completion timelines, and/or not meeting performance objectives. These objectives define whether a project is successful or not. The criteria for success should be agreed upon at the time of acceptance of the project by all parties, internal and external to the organization.

The uncertainties may also include questions of material and parts quality; delays in delivery of sufficient materials to meet project needs; budgetary and personnel changes; and, incomplete knowledge or research. These risks lead rapidly to delays in delivery dates and budget overages that can severely undermine confidence in the project and in the project manager. Since project risk management is process oriented, it remains possible to have a successful project and an unsuccessful product or service (for example, a construction project that meets or beats all time, budgetary, and quality requirements yet opens in a depressed real estate market.) While any project accepts a certain level of risk, regular and rigorous risk analysis and risk management techniques may serve to defuse problems before they arise or mitigate a risk. Risk management must also be a discipline requiring creative problem solving skills.

The common challenges in managing project risk have not changed, but the complexity of the systems and advances in technology have made the management of projects more critical, difficult, and expensive. The goal of risk management, according to Parnell (2008) is to enact a policy and take action to reduce the risk induced variance on performance, cost, and schedule estimates over the entire system life cycle. The effective risk assessment of any system is crucial to a "system decision problem." (Parnell, et al., 2008, p. 13) According to Parnell (2008) there are six core questions that are commonly used to capture various dimensions of program risk: (1) What can go wrong?; (2) What is the likelihood of something going wrong?; (3) What are the consequences?; (4) What can be done and what options are available?; (5) What are the trade-offs in terms of risk, costs, and benefits?; and (6) What are the impacts of current decisions on future options? (Parnell, 2008, p. 70)

Risk analysis is risk management in most cases. For large organizations, program managers and systems engineers focus on monitoring, measuring, and mitigating risks throughout a system's life cycle. Optimizing risk management by "tying" together all ship projects over its service life may prove advantageous in minimizing total ship cost and optimize operational availability. Additionally, why a life-cycle approach, particularly in vessel construction, repair, and maintenance? The answer may prove to be of some utility to the Navy and maritime industry by optimizing all a vessel's life time construction, repair, and maintenance evolutions under one cost center.

What are the trends in addressing these challenges?

"The past three decades, engineering management has evolved from …multiple objectives in modeling and decision making…to multiple criteria decision making (MCDM). MCDM has emerged as a philosophy that integrates common sense with empirical, quantitative, normative, descriptive, and value-judgment-based analysis." (Haimes, 2004, p. 188) The challenges in the management of risks for project managers would include risk: identification, assessment, analysis, and preventive/mitigation solutions. The most obvious challenge is to recognize and indentify potential risks to project completion.

The trends in addressing risk management are from an Enterprise Risk Management perspective of a corporate consumer, which are moreover similar problems as experienced in many industries: (1) measurement of results from either qualitative and/or quantitative origin, specifically intangible risks; (2) poor or non-existent planning processes or capabilities; (3) lack of acceptance of or need for risk management; and (4) corporate culture and behaviors unsuitable for change or improvement. And lastly, there are managers who refuse to reveal weaknesses in their organizational processes. The overall trend is to continue to conduct business as usual. The purpose of the research is to develop and apply a systems-based-framework for the analysis of project risk management performance.

2.6 Synthesis of the Literature of Life Cycle Principles

2.6.1 Life-Cycle Approach

The definition of a life-cycle will include the products original inception or design, its service life, and to include its final "resting place" as a discarded product. MIL-STD-882 applies to all aspects of DoD procurement items, systems, and materials and defines life cycle as: "all phases of the systems life cycle including design, research, development, test and evaluation, production, deployment (inventory), operations and support, and disposal." (MIL-STD-882D, 2000, p. 2) Life cycle cost (LCC) as defined by the Navy, includes follow-up ship acquisition cost, life cycle fuel cost, and life cycle manning cost. Annual life cycle costs are discounted to the base year, using an annual discount rate of 7%. Historical shipbuilding costs are inflated to the base year using a 5% average annual inflation rate from 1981 data. Producibility is also considered in the construction cost equations. Producibility factors are based on hull form characteristics, machinery room volume, and deck height." (Brown & Salcedo, 2003, p. 53)

The Navy has also come up with another metric for vessel costs, called the vessel Total Ownership Cost (TOC). There are two commonly used definitions of Total Ownership Cost. The first is very broad perspective and written for top-level DoD managers. "DoDTOC is the sum of all financial resources necessary to organize, equip, train, sustain, and operate military forces sufficient to meet national goals in compliance with all laws, all policies applicable to DoD, all standards in effect for readiness, safety, and quality of life, and all other official measures of performance of [sic] costs to research, develop, acquire, own, operate, and dispose of weapon and support systems, other equipment and real property, the costs to recruit, train, retain, separate and otherwise support military and civilian personnel, and all other costs of business operations of the DoD (Gansler, 1998)." (Boudreau & Naegle, 2005, p. 110)

The second definition of TOC is written from the vantage point of the Program Manager (PM) of the war-fighting system, and a subset of the definition of top-level DoD. Defense Systems TOC is defined as Life Cycle Cost (LCC). "LCC (per DoD 5000.4M) includes not only acquisition program direct costs, but also the indirect costs attributable to the acquisition program (i.e., costs that would not incur if the program did not exist). (Gansler, 1998)." (Boudreau & Naegle, 2005, p. 110) This concept is closer than previously held costs, and approaches the engineering management definition of a ship's life cycle.

All systems including projects have a life cycle, which is defined as its useful lifetime or service life. Additionally, from a project management perspective, there is a conceptual phase, a planning phase, a design phase, an implementation phase, a conversion phase, and an after-life phase (not shown below) where the product has become unable to meet performance requirements, become non-functional, and is to be recycled or discarded. A life-cycle approach includes from conceptual phase, and past the conversion phase to recycling or land fill.

The advantages from analyzing a ships service life provides a view of all aspects of the ship and permits a better perspective to manage its cost and schedule from a project risk management and life cycle perspective. Managing risks may provide better optimization of resources and time for a vessel's service life. It is the opinion of this author that economies may be obtained from a ship system life-cycle approach, and that from inception to disposal, economies can be obtained by using a project-risk management life-cycle perspective mentioned previously.

There are numerous defense reviews undertaken concerning the Navy's future force structure as well as the shipbuilding industrial base, for a myriad of reasons. The RAND National Defense Research Institute conducts many defense reviews at the behest of the various governmental agencies and departments. From earlier research, RAND identified types of issues and evaluated their capacity of analytical models in addressing specific issues. Quoting a RAND summary report, We found that the most common concerns of defense analysts were cost, schedule, industrial base capacity, shipyard performance, and program management strategies. Further, "we found existing tools lacked an integrated approach that would allow analysts to consider not just individual elements (e.g., manpower and procurement funding requirements) but the interaction and interrelationships among the industrial base components – from attrition rates to ship life extensions, from labor learning curves to overhead costs." (Arena, et al., 2004, p. XV) There are ten commonly used life cycle models, which are explained below:

1. The pure waterfall model consists of the following discontinuous phases: concept; requirements; architectural design; coding and development; and testing and implementation. The Pure waterfall model performs well for products with clearly

understood requirements or when working with well understood technical tools, architecture's and infrastructures, especially when split into subprojects at an appropriate phase such as after the architectural design or detailed design phases. Its weaknesses frequently make it inadvisable when rapid development is needed, which in these cases, a modified model may be more effective.

2. The spiral model is a risk reduction oriented model that breaks a (software) project up into mini-projects, each addressing one or more major risks. After major risks have been addressed, the spiral model terminates as a waterfall model. Spiral iterations involve the following steps: determine objectives, alternatives and constraints; identify and resolve risks; evaluate alternatives; develop the deliverables for that iteration and verify that they are correct; plan the next iteration; and commit to an approach for the next iteration. For projects with risky elements, it is beneficial to run a series of risk-reduction iterations which can be followed by a waterfall or other non-risk-based lifecycle.

3. The modified waterfall model used the same phases as the pure waterfall, but is not done on a discontinuous basis. This enables the phases to overlap when needed. Risk reduction spirals can be added to the top of the waterfall to reduce risks prior to the waterfall phases. The waterfall can be further modified using options such as prototyping, JADs or CRC sessions or other methods of requirements gathering done in overlapping phases.

4. The evolutionary prototyping uses multiple iterations of requirements gathering and analysis, design and prototype development, with the result analyzed after each iteration. Their response creates the next level of requirements and defines the next

iteration. The manager must be vigilant to ensure it does not become an excuse to do code-and-fix development.

5. The code-and-fix may be used if there is no methodology and rarely produces useful results, requiring little experience on modeling. This model is only appropriate for small throwaway projects like proof-of-concept, short-lived demos or throwaway prototypes.

6. The staged delivery model follows early phase deliverables of the pure waterfall, the design is broken into deliverables stages for detailed design, coding, testing, and deployment. Management must ensure that stages are meaningful to the customer. The technical team must account for all dependencies between different components of the system.

7. The evolutionary delivery model straddles evolutionary prototyping and staged delivery models. The initial emphasis should be on the core components of the system. This should consist of lower level functions which are unlikely to be changed by the customer.

8. The design-to-schedule model is a staged release model, however, the number of stages to be accomplished are unknown at the outset of the project. In this model, it is critical to prioritize features and plan stages so that the early stages contain the highest-priority features, leaving the lower priority features for later in the process.

9. The design-to-tools model approach, the capability goes into a product only if it is directly supported by existing software tools. If it isn't supported, it gets left out. Architectural and functional packages notwithstanding, these tools can be code and class

libraries, code generators, rapid-development languages and any other software tools that dramatically reduce implementation time. Consider the tradeoffs of time-to-market versus lock-in and functionally compromises. This may be an appropriate approach for a high-risk element of the overall project or architecture.

10. The off-the-shelf model following a requirements definition, analysis must be done to compare the package to the business, functional and architectural requirements. It is critical to know how the desired features compare with packaged set and if the packaged can be customized. Also, this model will rarely satisfy all system requirements.

The previously mentioned models have their applications, but this author is pursuing the approach of a purely project risk management and life cycle modeling of a complex system such as ship repair and maintenance. The purpose of the research is to develop and apply a systems-based-framework for the analysis of project risk management performance.

2.7 Synthesis of the Literature of Decision Management Principles

2.7.1 Decision Making or Decision Management

Decision making cab be regarded as an outcome of mental processes (cognitive process) leading to the selection of a course of action among several alternatives. Every decision making process produces a final choice. The output may be a decision (action) or ignoring the action either presently or in the future. Human performance in decision making terms has been subject of active research from both psychological and cognitive perspectives. From a psychological perspective, it is necessary to examine individual decisions in the context of a set of needs, preferences an individual has and values he/she seeks. From a cognitive perspective, the decision making process may be regarded as a continuous process integrated and in constant interaction with the environment. From a normative perspective, the analysis of individual decisions may be of concern with the rationality in making decisions including the rationality and unintended or unknown outcomes that may be created.

Engineering Management (EM), Decision Making (DM) and Multi-Objective Tradeoff-Analysis (MTA) are closely tied together, since EM decisions are often made with several options with varying impact and cost, or with a single option and the decision to do something, or nothing. Decisions can be made in a very thoughtful manner following various schools of thought favoring a particular option, depending upon the impact to the individual project, program, or company as a whole, and/or the calculated costs, whether monetary or intrinsic. What is largely missing from this literature search is the discussion on the context in which decisions are made in the shipbuilding and repair industry when projects and/or contracts exceed costs and time limits, and how a knowledge management system, if it is available and utilized by a manager-in-crisis, can produce better decisions that reduce or mitigate problems with budget expenditures and/or timelines. This researcher sees this area as untilled fields in the shipbuilding and repair industry, with tremendous potential for monetary savings.

Challenges to managing projects are the same for ship repair and maintenance (SR&M) as in other areas of business and industry: (1) insufficient resources; (2) time limitations; (3) inadequate staffing; (4) communication (internally and with outside contractors); (5) potential single-point failures (identify, evaluate & eliminate); (6) fasterbetter-cheaper (short term goals may be adverse to vessel life cycle goals); and (7) risk of project failure due to unanticipated events.

One question commonly asked is, "What is the basic model for Decision Making?" The Rational Decision-Making Model is one process for making logically sound decisions. (Robbins & Judge, 2007, p.33) The model comes from the field of organizational behavior. The process is logical and follows the orderly path from problem identification through solution. Rational decision making according to Scholtes (2003) may be summarized as a seven step model for making rational and logical reasons: (1) define the problem; (2) generate all possible solutions; (3) generate objective assessment criteria; (4) chose the best solution which has been generated; (5) implement the selected solution; (6) evaluate the success of the selected solution; (7) modify the decisions and actions taken based on the evaluation of step 6 success. Another perspective decision-making model is based on the premise that a decision-making process based on data leads to good decisions. (Scholtes, 2003, p. 47) The Author notes that although the premise appears valid, this may not always be the case in a complex system of projects or a complex project.

2.8 Framework for Project-Risk Management Development

In the Department of Defense risk management structure, "there are four process steps, with risk assessment further broken down into risk identification and risk analysis." (Conrow, 2003A, p. 179) This process is similar to that in the 2000 PMBOK Guide (Project Management Institute), except for the following: "First, risk analysis is split into qualitative and quantitative risk analysis process steps in the 2000 PMBOK Guide, whereas in the DoD Draft Extension it is treated as a single process step. Second, the

DoD Draft Extension emphasizes the feedback term present from risk monitoring (as shown in Figure 1) to the other process steps, which is not illustrated in the 2000 PMBOK Guide process flow (Conrow, 2000; DAU, 2002a)." (Conrow, 2003A, p. 179) Figure 6: DoD Risk Management Structure below, graphically shows the structure.

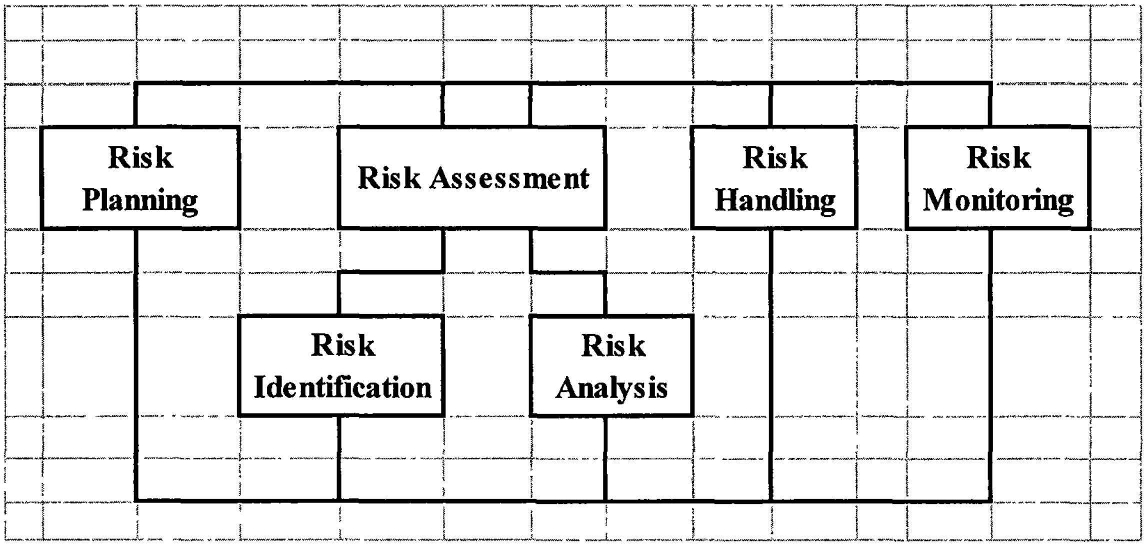


Figure 6: DoD Risk Management Structure
Adapted from Conrow (2003). *Development of Risk Management Defense Extensions to the PMI Project Management Body of Knowledge. Acquisition Quarterly, Spring 2003.*

The above figure shows the management structure of assessing and controlling risk in the Department of Defense; however, there is little in specific direction as to how far down the governmental chain-of-command this process is actually utilized by people in this less than transparent, large and complex organizational structure. The purpose of the research is to develop and apply a systems-based-framework for the analysis of project risk management performance.

2.9 Synthesis of the Literature on Applications of Project-Risk Management with Life Cycle Applications

2.9.1 Description of the best model fit for SR&M

The best model appears to be the design-to-schedule model (borrowed from the software field) as it is a staged release model, and the number of projects to be accomplished during a ship's life cycle is unknown at the outset of the ship's lifetime and would be best served from the project risk management life cycle approach. Software engineers traditionally considered any work after initial delivery (post ship construction) as simply software maintenance (similar to ship repair and maintenance). Further, this model divides this work into various tasks (ship projects), including making changes to functionality (upgrading ship systems and machinery), changing the environment (modifying ship configurations for future potential mission areas), correcting errors (repairing design errors, equipment, and system interfaces), and making improvements to avoid future problems (preventive maintenance).

2.10 Principles of Project-Risk Management Development

One may ask, what is the importance in project risk management? Project Managers, Project Risk Managers, and/or Operational Risk Managers, are concerned with the efficient and effective management of a project and their organization. In particular, they address the risk profile of the project within the organization and the likely impact of loss resulting from the probability of failure due to internal and external events, people, systems, procedures, and processes. Risk management impacts directly or indirectly on an organization's bottom line performance. It is becoming central to operational fundamental analyses, and most recently including the assessment of management, their strategy, and the expected long-term performance of the organization. The optimization of the risk-reward relationship is enforced by optimizing stakeholder value, to increase the organization's competitive position, and to make the efficient and effective use of capital. In addition, good risk policies and procedures, properly executed, are necessary for quality customer service, which leads to a satisfied customer base, and predictable and more stable cash flows.

Given the increase in sophistication and complexity, together with the inexorable drive towards consolidation and/or specialization in many industry sectors, risk management is being seen as a potential differentiator and a source of competitive advantage. "Although the Department of Defense's (DoD) current risk management direction presents a comprehensive and robust approach to identifying, assessing, and managing risk, it does not adequately emphasize the interface between risk management and contract administration." (Bolles, 2003, p. 151) Emphasis in this study will be placed on the "quality" of management and their ability to correctly assess, manage and optimize risk in management of ship repair and maintenance (SR&M) projects during their 35-year service life. The purpose of the research is to develop and apply a systems-based-framework for the analysis of project risk management performance.

2.11 Synthesis of the Literature on Project-Risk Management Principles

Bolles (2003) stated that, "In essence, a well crafted, risk-appropriate contract can temper the sensitivity between technical risk and the probability of cost and schedule overruns, while a poorly crafted contract can actually increase the probability of cost and schedule overruns. By better linking sound risk management practices with sound contract administration practices, the DoD stands to continue being the bellwether federal agency for pushing the state-of-the-art in effective risk management." (Bolles, 2003, p. 143) The above statements remain in effect on paper, however the practice remains a problem due to the complexity of projects, management efforts and limitations, and the huge size of the government project undertaking by numerous federal agencies, bureaus, and departments.

2.11.1 Gap Analysis

The gaps in the literature have indicated very little relative to project risk management with a life-cycle management approach by any organization or sector, more specifically in the design and construction, repair and maintenance, and deconstruction of naval vessels. The Navy, through the offices of Naval Sea Systems Command (NAVSEA) oversees and manages all construction, repair, and maintenance of vessels for the United States Navy. Reviewing numerous Department of Defense directives, there is only scant mention of a life cycle view, which by the Defense Acquisition System 5000.01. In theory it is practiced in the acquisition of equipment, systems, parts, and materials, but has yet to be realized in the management of a ship's service life to optimize maintenance and repair schedule and reduce total ship cost.

2.11.2 Gaps in Practice

A U. S. House of Representatives Systems Development Life-Cycle Policy dated March, 24, 1999, briefly indicates that one of the management control objectives under "Project Definition" is risk analysis and under "User Requirements Definition" is risk assessment. The risk analysis provides a description of internal control and security vulnerabilities, the nature and magnitude of associated threats, and potential for loss or disruption to service. The analysis also includes recommendations for mitigation and safeguards for identified risks. Additionally, life-cycle is defined as referring to the entire period of activity in transforming customer needs into system or support solutions and sustaining activities. (HR, 1999, p. C1) The previously mentioned policy statements are from and for the House of Representatives and their research facilities and organizations, but they do not direct nor require the Executive Branch of the government, specifically the Department of Defense, to comply.

Reviewing numerous Department of Defense directives, there is only one mention of using a life cycle approach, and that is for the Defense Acquisition System 5000.01. The Navy, through the offices of the Naval Sea Systems Command (NAVSEA) oversees and manages all construction, repair, and maintenance of vessels for the United States Navy. In a 2008 OPNAV N5F Report to Congress on the Navy Force Structure and Shipbuilding Plans Background and Issues for Congress for 2009, the only mention of "life cycle" is termed vessel service life, which precludes shipbuilding and retirement.

2.11.3 Gaps in the Existing Literature

A major gap in the existing literature existed in the treatment of project risk management with life-cycle development projects as an integral part, subservient to the organized complex whole, ergo a complex system. The main focus points are:

- Risk-based life-cycle impacts on system outcome to attain full ship service life.
- Risk-based life-cycle tradeoffs on system costs over ship service life.
- Risk-based life-cycle tradeoffs for system viability over ship service life.
- Consideration of system life cycle cost over system phase costs.

- Consideration of system life-cycle tradeoffs and impact among system cost factors.
- Consideration of system stakeholder's feedback with decision makers.
- Recognition of system stakeholder's non-commensurate and opposing objectives.
- Recognition of system complexity and its affect and impact of risks.
- Recognizing the stakeholder career or "rice-bowl" factor.

The project management community, especially the engineering management discipline, has been less than forceful in the integration of project management and risk management processes in system and sub-system applications, and to foster better understanding of a socio-technical system in which each of the development and management processes reside. As of this writing, this author has found no exceptions to the above bullet statements. The concern here is that risk analysis, risk procedures, and the outcome-based success evaluation probabilities are being neglected or viewed as unimportant or not cost effective to create, implement, and/or execute. In the complex systems of ship repair and maintenance, the perspective from an engineering manager can be no less than foolhardy at best.

There are gaps in the literature for applying a life-cycle approach relative to ship repair and maintenance. Studies indicate, from a commercial perspective, that a vessel's hull integrity is paramount in delineating high cost (Ship B) versus low cost lightship (Ship A) weight which optimizes a vessel's cargo carrying capacity. "Ship B is a ship of identical form and displacement to ship A but with a higher lightship weight due to greater corrosion allowances and particularly so in selected areas commensurate with present industry experience in order to minimize steel renewals." (Gratsos & Zachariadis, 2008, p. 3)

IBM has Product Lifecycle Management (PLM) solutions to meet commercial vessel construction pressures to minimize costs and meet delivery dates. Shipyards are also experiencing increased pressures from owner and operators, whose tolerance for cost overruns, delivery delays, rework and poor quality is eroding. “The long-term operating profitability of a ship depends, in large part, on quality construction, maximum cargo capacity, energy efficiency and design that requiring a minimal crew to operate. A ship is a product with a 20 to 40 year lifespan.” (IBM, 2006, p. 3)

For Systems Manager versus Project (Risk) Manager, the “gap” in the literature is that project managers (e.g. Commanding Officers) are concerned with project risks as their only view in the current system (e.g. ship condition and its ability to perform mission essential deployments). The Project Managers may also be concerned with immediate project risks as well, their interest in long range system performance (e.g. vessel or vessel class material readiness towards vessel viability during its projected service life). There is also a “gap” in project management in that there are always political as well as budgetary issues at odds with technical issues of any project, competing for corporate and/or departmental funds or resources. Current Navy practices are:

- ✓ Establishing a ships’ service life of 35 years
- ✓ Emphasis on total ownership costs
- ✓ Budgets reduced causing limited or shrinking resources
- ✓ Periodicity of inspections and maintenance cycles
- ✓ Reliability-Centered Maintenance (RCM)
- ✓ Condition-based inspections and maintenance
- ✓ Hierarchical organization

- ✓ Decision making authority for a ship's repair and maintenance availability

The Navy has determined that the warships in the fleet must have a service life of 35 years to support current and future anticipated funding. This service life excludes the design and shipbuilding, and the transition to fleet reserve status, decommissioning, or foreign sales. Within those 35 years Commander Naval Surface Forces Atlantic (COMNAVSURFLANT) launched in fall 2002, SHIPMAIN, which is, "improve maintenance planning for surface ships and nonnuclear aircraft carriers, from the point at which work is first identified by ship's force through the start of execution of that work in maintenance availability. It concentrates on gaining efficiencies across multiple organizations by identifying and eliminating redundancies." (Yardley, Raman, Riposo, & Chiesa, 2006, p. 23) SHIPMAIN, an anachronism for Ship Maintenance, was to "improve the timeliness and quality of ship work candidates, as measured by the newly instituted metrics of Ship to Shore Cycle Time and Ship Work Candidate First Pass Yield." (Sydow, 2008, p. 90) The cost of construction of these next-generation ships, budgetary restraints, and other factors have also made it necessary to maintain, adapt, and extend the life of the legacy fleet to meet operational requirements and maintain our maritime dominance. (Dean, Reina, & Bao, 2008, p. 81)

NAVSEA has conducted several interdisciplinary studies to address the high cost and extended duration of new vessel design and construction cost overruns. Naval architecture and force studies have been key components of these efforts. "Two general approaches are available: development of alternative future fleet design and programming concepts, and changes in expected service life policy. These are not mutually exclusive alternatives; service life is a key variable in future force planning regardless of any other variables considered." (Koenig, et al., 2008, p. 1) "The Navy has not conducted a comprehensive study of a ship design to determine the relationship between cost-to-design-and-build and years of intended service life." (Koenig, et al., 2008, p. 5)

Furthermore, the average age of the fleet will increase, so maintenance, repair, and modernization budgets will eventually rise. The Navy has a requirement to maintain 313-ship fleet over the next thirty years, and per-ship costs are rising. (Koenig, et al., 2008, p. 5) Currently, the anticipated force structure of the "current 30-year shipbuilding plan was based on a 35-year average expected service life of naval ships, which was asserted to be too long unless huge investments were made to keep old ships operational well beyond their intended and historical service life." (Koenig, et al., 2008, p. 5) "The Navy will add five years to the planned 35-year service life of its workhorse Arleigh Burke-class destroyers, according to the latest version of the service's 30-year shipbuilding plan ..." (Koenig, et al., 2008, p. 5)

Navy leaders embarked on an "Enterprise" approach to operational readiness to deal with changing challenges of the 21st century. One CNO initiative is "Operations-Focused Maintenance" program. According to the Chief of Naval Operations, the Fleet Response Plan (FRP) is the operational framework intended to "...ensure continuous availability of trained, ready Navy forces capable of a surge response forward on short notice" (OPNAV INSTRUCTION 3000.15, August 31, 2006, p. 1). "The FRP is the construct within which the SWE (Surface Warfare Enterprise) must function. Implicit in the concept of the FRP is the need for high operational availability (AO) of naval forces. High AO directly affects the frequency and duration of maintenance opportunities." (Sydow, 2008, p. 90)

Project Risk Management from a life cycle application may minimize vessel total ownership cost to include design and construction, repair, and maintenance, optimize the scheduled for maintenance periods, and increase operational availability and surge readiness. Figure 7 provides a current view of the Navy's SR&M framework based on collected documentation and interviews.

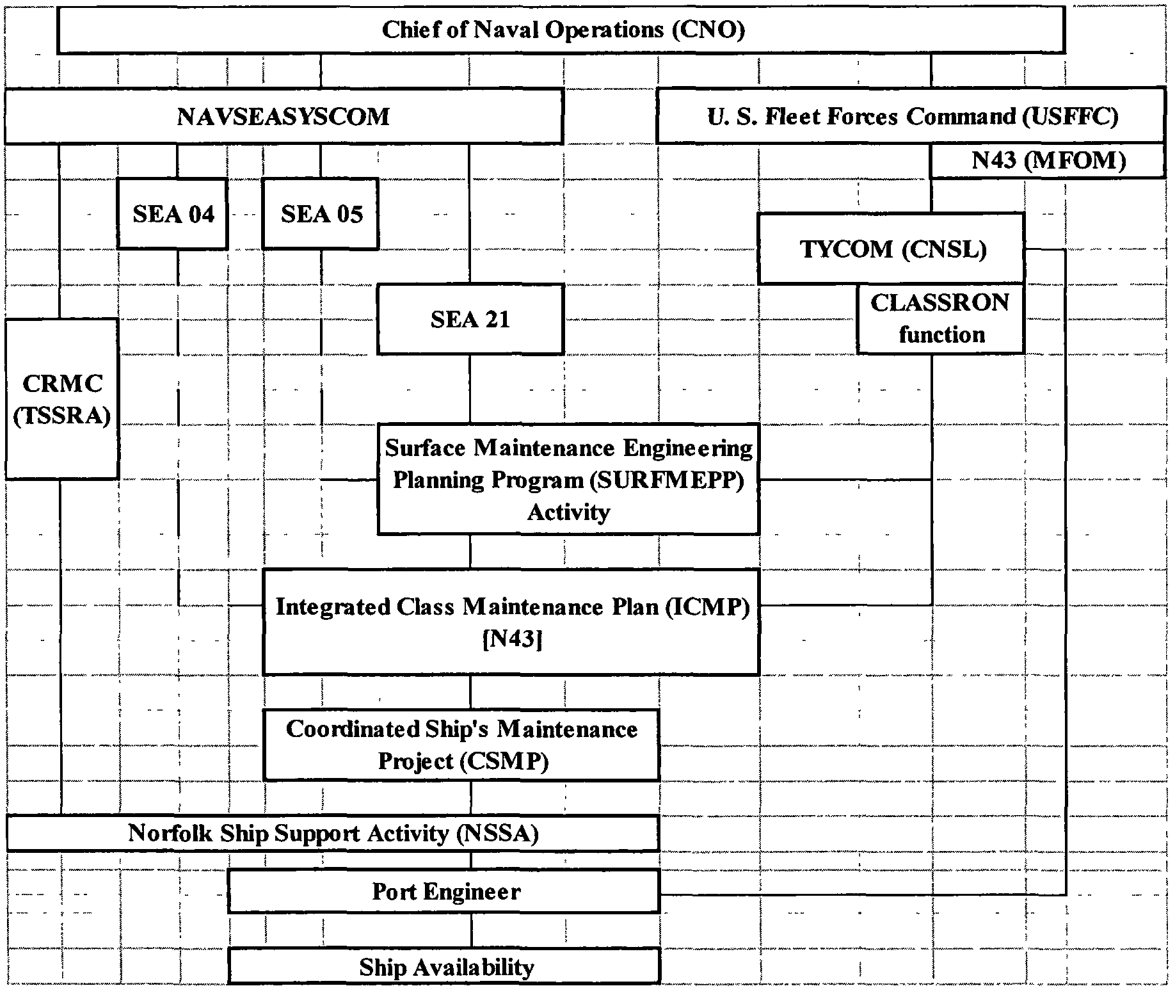


Figure 7: Current Navy Ship Repair & Maintenance Framework

2.12 The Relationship of Research to Theory and Practice

This section provides a review of the literature contained in all four threads of the review: systems engineering principles; project risk management development; life cycle management; and project risk management performance. It focuses on the empirical studies that have contributed to the research and provided the foundation for the development of the framework for project risk management. Appendix B shows the gap in the literature surrounding the application of systems principles to project risk management which served as the focal point for the research.

The purpose of the research is to develop and apply a systems-based-framework for the analysis of project risk management performance. Because the current traditional method of project management performance, in terms of sub-system performance may be too restrictive, with a more holistic and systemic view may reveal a more optimum look at performance outcomes. The framework provides the conceptual basis for understanding the context of project risk management and life cycle project applications, but will also support the development of formal methodologies that may be used by project manager practitioners to improve project performance.

The strength of the framework has been based upon theoretical constructs derived from systems theory. Development of the framework used the categories, attributes, relationships, and dimensions of framework drawn from Figure 8: Literature Threads.

Figure 8 has been included to illustrate how the four research threads come together to from the development of the framework. The concepts are as follows:

1. A number of systems based principles and concepts exist in the literature that may be applied to the research question.

Application to Systems *Engineering Principles*	**Project Management *Development***	**Project Risk Management *Development***	**Project Life Cycle Management *Performance***
Arena et al (2004)	Elonen & Artto (2003)	Andrews et al (2004)	Ari et al (2008)
Bahill & Botta (2008)	Eve (2007)	Ayyub et al (1993)	Brown & Salcedo (2003)
Bayhill & Smith (2009)	Freimut et al (2005)	Bayhill & Smith (2009)	Cowell et al (2002)
Brown & Salcedo (2003)	Freimut et al (2005)	Bolles (2003)	Haimes (2004)
Conrow (2003)	Hanish et al (2009)	Cabano (2005)	Hitchcock et al (1998)
Daniels & LaMarsh (2007)	Hussain & Wearne (2005)	Caddell et al (2005)	Hofstetter et al (2002)
Dasher (2008)	Johnson (2006)	Clark & Besterfield-Sacre (2009)	ISO/IEC 15299 (2000)
Garvey & Pinto (2009)	Kerzner (2004)	Conrow (2003)	Koenig et al (2008)
Gharajedaghi (2004)	Kolltveit et al (2005)	Cowell et al (2002)	Mathews et al (2002)
Haimes (2004)	Letens et al (2008)	Cox (2008)	Mead et al (2000)
Haimes (2009)	Morris & Jamieson (2005)	Cox (2009)	Owens (1997)
Haimes (2009)	Palomo et al (2007)	Dillon et al (2003)	Sargent et al (2006)
Keating et al (2008)	Powell & Buede (2006)	Garvey & Pinto (2009)	Asset Life Cycle Model for Total Cost of Ownership
Keating et al (2003)	Roberts et al (2003)	Goddard, et al (dnload 060908)	US Navy Maintenance and Modernization Business Plan
Keating et al (2008)	Sargent et al (2006)	Haimes (2004)	Wideman (2004)
Koenig et al (2008)	Shtub & Globerson (2005)	Henry & Haimes (2009)	
Letens et al (2008)	Soderlund (2002)	Hofstetter et al (2002)	
McCumber & Sloan (2002)	Wideman (2004)	Holmes et al (2009)	
Padilla et al (2009)	Williams (2005)	Kimbrough & Componation (2009)	
Pinto et al (2006)	Wysocki (2007)	Lowrance (1976)	
Powell & Buede (2006)	Yeo (2002)	Mathews et al (2002)	
Starr (2000)	Young (2004)	Mausser & Rosen (1999)	
Williams (2005)	Zwikael & Gonen (2007)	Morgan et al (2000)	
Yardley et al (2006)		Morris & Jamieson (2005)	
Yeo (2002)		Olsen et al (1998)	
		Owens (1997)	
		Palomo et al (2007)	
		Peltier (2005)	
		Pinto & Pathak (2008)	
		Pinto et al (2006)	
		Pinto et al (2006a)	
		Seiler (1990)	
		Seyedhoseini et al (2008)	
		Starr (2000)	
		Zwikael & Gonen (2007)	

Figure 8: Literature Threads

2. Systems based methods and models exist that may be adequate to holistically describe the project risk management process.

3. Few existing project risk management development frameworks and/or methodologies address the overall development process holistically.

4. There has been limited application of life cycle management principles associated with project risk management development and the root causes of poor project performance.

The four concepts encompass all of the relevant journal articles from the literature review. These four concepts provide a structure that has been used as an endorsement of the research by supporting the unique purpose, objectives, and research questions.

2.13 Critique of Findings

The review of the body of literature has been conducted with the focus on gaps in the research and the need for additional empirical research related to the research purpose and primary research questions. The use of the synthesized literature in systems engineering, project management, risk management, life cycle management, and decision management elements of the research included a discussion of its purpose and the explicit boundaries it sets for the researcher.

2.14 Summary

The chapter has shown how the research related systems principles to project risk management life cycle development and performance. It has presented the schema and breadth of the literature review. It has provided a synthesis of the salient facts and exposed gaps in the literature, highlighting the need for additional empirical research. The chapter provides a solid literature-based foundation for the overall research effort and the extant literature required to build the framework. The inclusion of an expert opinion and review, outside the researcher, decreased research risk and added validity to the literature used. The additional literature sources, recommended by an expert reviewer, provided additional empirical facts that were used in the framework. As a reminder, the purpose of the research is to develop and apply a systems-based-framework for the analysis of project risk management performance.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter reviews the high-level research and dissertation concept and provides a detailed description of the research paradigm in terms of the researcher's view and the problems under study. It also provides the rationale for the selection of a mixed method design and reviews the challenges presented by both the survey and case study elements of the research. Lastly, it concludes by stating how the research complied with the Cannons of Science.

3.1 Empirical Science and Methodology

The principle role of the researcher is "... the creation of theory and the providing of empirical support for theory." (Camilleri, 1962) The methodology used for this research study embraces the aspects of scientific quest and provided a solid base for conducting empirical science. Herbert Blumer (1970) identified six elements, that are indispensible to making an inquiry in empirical science: (1) The possession and Use of a Prior Picture or Scheme of the Empirical World Under Study, which implies a review of the literature related to and context surrounding the phenomena as it exists in the empirical world; (2) The Asking of Questions of the Empirical World and the Conversion of Questions into Problems, which is the beginning of the inquiry where the structure of the problem determines the broad methodological approach to be used; (3) Determination of the Data to be Sought and the Means to be Employed in Getting the Data, specifying that the data requirements help solidify the specific methodology and technique used to collect empirical data for the inquiry; (4) Determination of Relations between the Data, forming the data connections form the basis for the findings, as well as the specific techniques and procedures used for understanding the connections selected and invoked based on the form and character of the data connections; (5) Interpretation of the Findings, which enable the findings of the study to be related to the outside body of knowledge, transcending the study; and (6) The Use of Concepts, that are the significant elements the researcher invokes that act as anchoring points for the interpretation of findings. (Blumer, 1970)

The methodology described in this chapter and the research design and detailed procedure in the next chapter specifically address each of the six fundamental elements of empirical investigation. In so doing, the researcher was able to execute the principles of science to ensure that the impulsive and stubborn empirical world could be studied within an acceptable framework of scientific investigation.

3.2 Research and Dissertation Concept

The research methodology selected for this study was a mixed method in that it used both qualitative and quantitative analysis methods to achieve the study purpose by answering three principle research questions. The value of a mixed method research design was that the strengths of each method were applied to the applicable question: How does 'systems engineering theory' in applying project risk management and life cycle assessment for scheduling ship inspections, repairs and maintenance improve operability and reduce ownership costs?

This question required the use of a qualitative element where a subjective approach was used to understand the question within its contextual environment. "Interpreting information technology in terms of social action and meanings is becoming more popular as evidence grows that information systems development and use is a social as well as a technical process that includes problems related to social, organizational, and conceptual aspects of the system." (Kaplan & Ducheon, 1988) Their statement(s) may also be assumed to apply to all aspects of any system where people and "things" are involved in a process, which in this study involves a complex system of and for project risk management life cycle applications.

A secondary question that logically follows is: How will the application of a systems-based framework using project risk management and life cycle assessment affect ship performance? Asking this second question throughout the development of the framework could provide feedback to assure its utility to practitioners, but the quantitative data may be years in the future after several operating cycles (18-month duration each) produce tangible results that may be verifiable. This required the use of a quantitative element where an objective approach was used to validate the utility of the framework on real world vessel projects. The ..."rationale for conducting an exploratory study is to develop pertinent hypotheses and propositions for further inquiry." (Yin, 2003) A case study design was selected in order to study program and project management techniques within their real world context. According to Yin (2003) case studies are applicable to inquiries that will:

- Investigate a contemporary phenomenon within its real-life context, to include areas where boundaries of phenomenon and context are not clearly evident.

- Cope with the technically distinctive situation in which there will be many more variables of interest than data points, in instances where one result may rely on multiple sources of evidence, permitting the data to converge in a triangulating fashion, or permitting another result.
- Benefit from the prior development of theoretical propositions to guide data collection and analysis.

Figure 9 depicts the high-level view of previously discussed research elements.

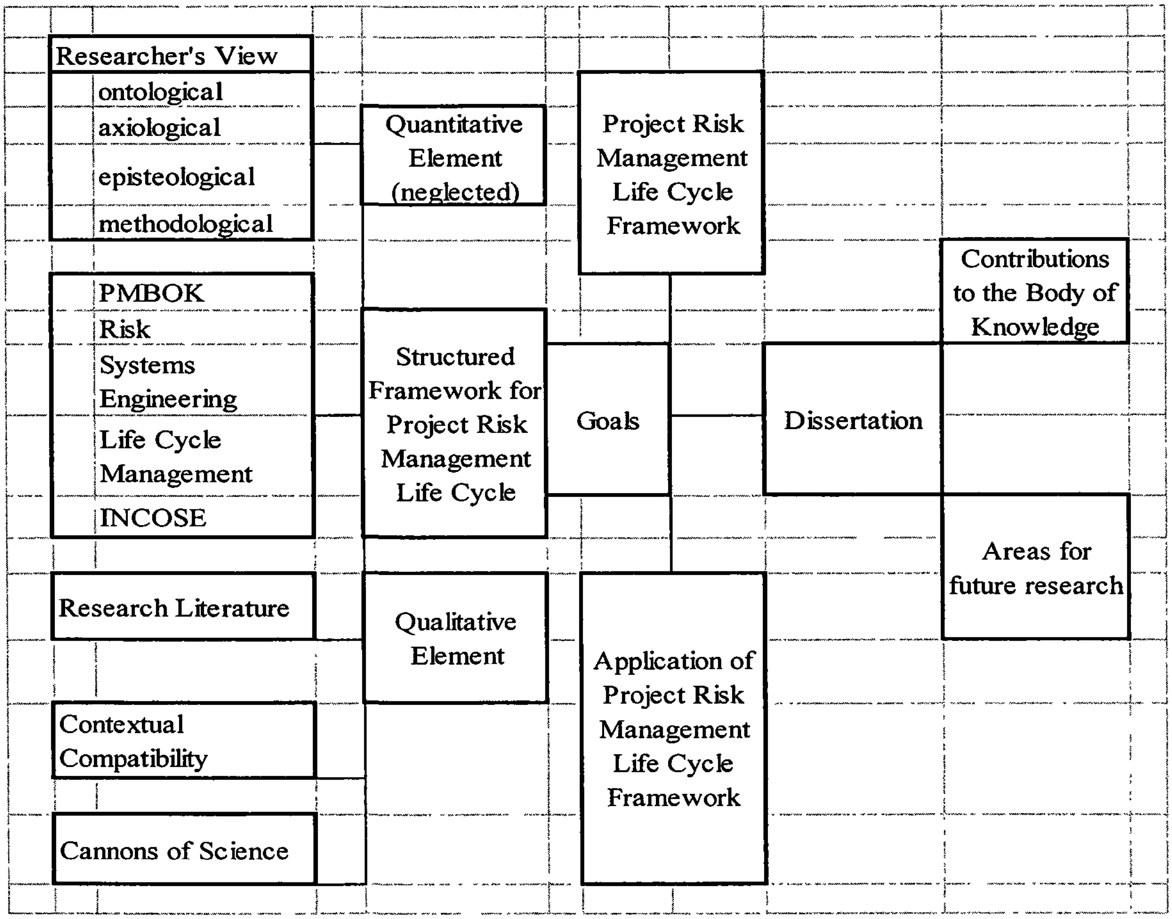


Figure 9: Research and Dissertation Concept.

The system-based framework developed in this qualitatively-based exploratory element was validated from senior ship repair and maintenance (subject matter experts) directors or program managers from each node of the command structure, to verify the framework and validate its potential for success.

3.2.1 Inputs to the Research Design

The research design was affected by five inputs:

1. Contextual Compatibility. For researchers using qualitative inquiry, context plays a major role in each of the various analytical approaches. Researchers must understand the importance of context and its essential nature in being able to understand and interpret contemporary phenomena that includes a societal element. Context becomes a very important part of the research methodology. Mishler (1979) notes that meaning is always within context and the contexts incorporate meaning. Miles and Huberman (1994) more strongly state that "... understanding contexts is critical. Even that adjective is too mild." A socio-technical system is a rich contextual environment, and in a complex systems and/or project risk management environment, it is also a part of the analytic strategy in the research design. "The ontological, epistemological, axiological, and methodological viewpoints all have a direct affect on the context of the research study." (Miles & Huberman, 1994, p. 56)

2. The Researcher's View. Theoretical and philosophical perspectives of a researcher are directly represented by the ontological, epistemological, axiological, and methodological views of the researcher in the conduct of his/her research.

3. The Project Management Body of Knowledge (PMBOK). The PMBOK is "... the sum of knowledge within the profession of project management." (PMI, 2004) Generally

speaking, the guide includes "... proven traditional practices that are widely applied, as well as innovative practices that are emerging in the profession..." (PMI, 2004, p. 81)

4. Research Literature. The body of literature on research methods and techniques provided the researcher with proven methods for the conduct of this research.

5. The Cannons of Science. The Cannons of Science provided a universally accepted scientific standard for this research.

All five inputs are necessary and influence the research design, governing the conduct of the research study.

3.3 The Research Perspective

Creswell (2003) has conceptualized his ideas about research into a model, showing the series of interrelated decisions that form the process of designing research. Figure 10: Research Design Elements is based on Creswell's model and depicts how the elements of the traditional research paradigm were translated into the design processes for this research.

Research Element	**Data Collection Methods**	**Data Collection References**	**Data Analysis Methods**	**Data Analysis References**	**Expected Outcomes**	**Relationship to Research Question**
Theoretical Framework Development	Literature Review	Snyder (1999) Ducasse (1951) Miles & Huberman (1994)	Deductive Theory Building	Carlile & Christensen (2005) Corbin & Strauss (1990) Glaser & Strauss (1967) Strauss & Corbin (1998)	Holistic, structured framework for project risk management of complex systems	Supports Research Question
Framework Validation	Case Study Method	Yin (2003) Miles & Huberman (1994)	Case Study	Yin (2003)	Framework Validation	Supports Research Question

Figure 10: Research Design Elements.

Leedy and Ormond provide guidance on the choice between quantitative and qualitative paradigms for research. See Table 1 below delineates the beliefs with the choice of potentialities from either the experimental and/or non-experimental approaches.

Use this approach if:	**Quantitative/Non-eperimental**	**Quantitative/Experimental**
One believes that -	There are multiple possible realities constructed by different individuals	There is an objective reality that can be measured
The audience	Supportive of qualitative studies	Supportive of quantitative studies
The research question	interpretive & exploratory	predictive & confirmatory
The availably literature	limited	relatively large
The research focus	involves in-depth study	great breadth
Available time	relatively long	relatively short
Ability/desire to work with people	high	low to medium
Desire for structure	low	high
Skill areas	attention to detail & inductive reasoning	statistics & deductive reasoning
Writing skills strength in area of study	narrative writing & literary	technical & scientific writing

Table 1: Research Perspective Elements
Adapted from Leedy and Ormrod (2001) *Practical Research: Planning and Design* (7th ed.).

Asking these questions may help refine the direction of a research effort, especially crucial for a complex study which is dependent on relationships, multiple frames of reference, multiple objectives and values, and risk. The answers to these questions tend to lead this study to that of a quantitative, qualitative, and quasi-experimental research.

3.4 The Research Viewpoint

The research framework example that underlies any research perspective describes the following set of basic assumptions for conducting research. (Iivari, Hirschheim, & Klein, 1998):

- Ontology – the structure and properties of what is assumed to exist.
- Epistemology – the nature of knowledge and the proper methods of inquiry.
- Axiology – the responsibility of a researcher for the consequences of his/her research approach and its result.
- Research Methodology – the procedures used to acquire knowledge.

The researcher's perspective and viewpoint are a function of his/her value system, normative behaviors, and perceived role. "The role as a researcher was a new one and as such was affected by a number of important relationship values." (Schein, 2002) Of particular note is that the theoretical and philosophical perspectives that influence any researcher are the ontological and epistemological views that a researcher brings to the research.

Ontology is concerned with the theoretical perspective that lies behind the knowledge claims: "In general, epistemological assumptions are concerned with the nature of knowledge and the proper methods of inquiry. By inquiry we mean the procedures or means by which we can obtain knowledge." (Iivari, et al., 1998)

"Qualitative research stands for an approach rather than a particular set of techniques, and its appropriateness – like that of quantitative research – is contingent on the nature of the phenomena to be studies." (Morgan & Smircich, 1980) As this study was a mixed method research, the researcher interacted with the participants. "The qualitative researcher often goes to the site [office or base in this case] of the participants to conduct the research. This enables the researcher to develop a level of detail about the individual of place and to be highly involved in actual experiences of the participates." (Creswell, 2003)

Axiology refers to what is valued as being right. Another term for this element is commonly referred to as ethics. Norman Augustine separates ethics into two categories: "... macro ethics which involve ethical issues that affect large segments of society; and micro ethics that affect a smaller, more immediate group, such as one's boss or one's client." (Augustine, 2002) Accordingly to Leedy and Ormrod, "Most ethical issues in research fall into one of four categories: protection from harm, informed consent, right to privacy, and honesty with professional colleagues." (Leedy & Ormrod, 2001) Protection from harm, whether physical or psychological, was the focus towards the research participants in the research design. The design of any research includes safeguards for participants in the research, both human and organizational, keeping them informed ahead of time as to what to expect as the study progresses. One additional issue under this umbrella would be the level of sensitivity of the research outcome and publication as well as any potential political ramifications. Informed consent explains that the participants, both human and organizational, were informed that the research study is strictly voluntary. They were told of the nature of the study and the specific activities they would participate in as well as their involvement. Right to privacy includes: "Any research should respect participants' rights to privacy. Under no circumstances should a research report, either oral or written, be presented in such a way that others become aware of how a particular participant responded of behaved." (Leedy & Ormrod, 2001)

The above three categories relate to human subjects engaged in a research study. Under these circumstances, the research required review and formal approval from a governing authority in accordance with the 1974 National Research Act. Since the passing of the act, the Belmont Report (HEW, 1979) serves as the primary ethical framework for protecting human subjects in the United States. The report focuses on biomedical and behavioral research involving human subjects. At Old Dominion University, the Human Subjects Institutional Review Board (IRB) ensures that all research involving human subjects conforms to federal, state, and local policies in providing protection of human subjects. As an aside, the subjects in this study were not the focus of this research, but only used to validate the proposed theory relating to the research question, as such, an IRB waiver is not be needed.

The final category, honesty with professional colleagues, has two elements:

- The researcher is required to report findings in a complete and honest fashion, avoiding misrepresentation of facts or intentionally removing information from the study. The researcher must remain neutral per the Cannons of Science. The research design must provide assurance that any personal prejudices and bias do not enter into the study.

- The researcher must show ethics in all phases of the research study. Most important is to properly cite ideas and concepts that belong to, originated from, or were expressed by others. This crucial element is a meticulous and continual challenge, sustained throughout this research study.

This researcher is focused on the problem under study, with a methodological view utilizing a mixed-method research. Further, the researcher endeavored to ensure that the research design provided adequate rigor, complying with the Cannons of Science. Additionally, this researcher focused upon the case study method using both qualitative and quantitative methods to optimize the triangulation of data.

Each methodology has supporting methods and with the central focus to be used for data collection and analysis. There was no restriction on choosing a specific method of information collection during the research study. The principle factor was answering the problems under study.

3.5 The Problem Under Study

The problems under study were the scope and focus of the research purpose. The boundaries were the research method and the Cannons of Science. Details of the problems were contained in the scholarly literature search, the research questions, the hypotheses, the data collection requirements, and the intended audience for the research study. Continual review of these details enabled the researcher, from the previously described ontological, epistemological, and axiological view, to make rational decisions as the methodology to employ.

3.5.1 Research Questions and Propositions

In answering the above questions for the proposed research, the researcher was able to determine that this research required qualitative elements from the case study. In addressing the research questions effectively, this approach would be adequate to provide the triangulation necessary for validation. Thus case study method approach was the logical approach to meet the goals of the researcher. A review of the research purpose helped to narrow the selection of specific qualitative methods. In this case, the proposed research was to develop and a systems-based framework for project-risk management and life cycle assessment on complex projects. The proposition is directed by the high-level research questions previously in Figure 12.

- The first question: How can systems engineering theory use project risk management and life cycle assessment to improve the ship repair & maintenance process?
- The second question: What outcomes will result from the application of a systems engineering based analysis framework for ship project risk management and life cycle assessment in selecting work items for a ship's availability?

Because the research questions contained both how and what questions, the study demanded both explanatory and exploratory elements. The "how" question required a subjective approach where the rationale for conducting the study was to develop specific hypotheses and propositions for further inquiry (Yin, 2003). In this case, this researcher used case study research for theory building to construct and build an engineering management based framework for the analysis of project risk management life cycle development to optimize complex project performance. The method required a literature intensive research effort to provide the platform for the idea and concept. The systems concepts of holism, complementarities, satisficing, and sub-optimization of the facts, provided a new perspective or point-of-view. The initial idea regarding a holistic, structured, systemic framework for project risk management life cycle development was supported by the literature review and served as a focal point for the framework development.

The "what" question required the use of an objective approach where the researcher used an empirical method to validate the utility of the framework on actual case studies of real projects. As the validation of the framework explored real-world processes, activities, and events in their natural setting, the case study emerged as the obvious method for validating the proposed framework of project risk management on a complex system, using a whole life cycle approach.

Documents related to the case were collected and analyzed to corroborate and augment evidence from other sources (Yin, 1994). Throughout, attention was focused towards the data design to ensure that thoroughness and the measures of design quality were kept at the fore front of this research.

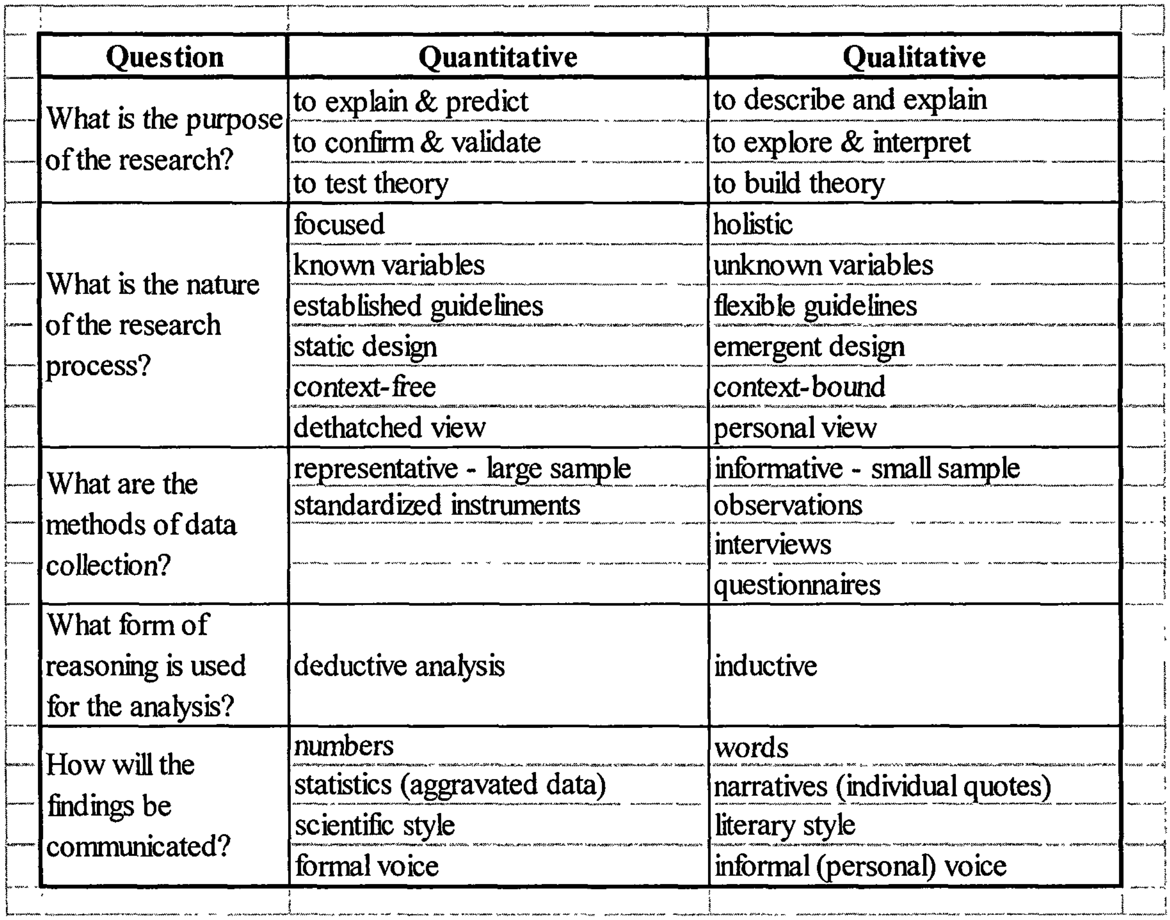
"Naturalistic inquiry is heavily dependent on the perceptions and thoughts of the researcher as the investigator is positioned as the instrument." (Lincoln & Guba, 1985) A journal was not kept, but notes were taken to capture reflections on the case study process, thoughts about the methodological design choices, and to help maintain a distinction between the role of researcher and that of designer. The context of the journal was meant to serve as another source to corroborate existing data. The contents included notes from observations, conversations with case sources, reflections about potential emerging themes and methodological direction changes or deviations.

3.5.2 Intended Audience

Project management is changing and evolving. PMI has much to offer as does authors like Kerzner who proposes “Enterprise Management” as the solution to successfully manage complex projects. (Kerzner, 2004) To this end, the Department of Defense has issued a “Business Management Modernization Program to address System Compliance Certification Process for Domains and Program Managers.” There are many instructions and directives issued by various governmental organizations and echelon managers. See Appendix B. The number of project management techniques and tools are as numerous as the companies who use their own version of project management methods, compounded by the number of project managers full filling that position. These unique industry craft-based practices or methods, however specialized to fit individual corporate needs and situations, still have less than overwhelmingly satisfactory completion rates, as determined by meeting a predetermined schedule and/or keeping within budgetary constraints.

3.6 The Rationale for Selecting a Case Study Method Design

The case study method research design was selected in response to the research question. This method will adequately address each of the questions. The methodology brought distinct qualities and biases to the research and it was incumbent on the researcher to ensure that both the principles of good research and the specific method were invoked. Leedy and Ormrod (2001) provide a set of conditional questions that include elements from the researcher’s view and the problem under study to guide the researcher. Their conditional questions are consolidated in Table 2 below, although the quantitative approach was not used. The qualitative approach was selected and used as a quantitative approach would have been very difficult due the enormity of SR&M data and the sensitivity of the repair and maintenance of classified systems and equipment as well as other national security concerns not addressed.



Question	Quantitative	Qualitative
What is the purpose of the research?	to explain & predict	to describe and explain
	to confirm & validate	to explore & interpret
	to test theory	to build theory
What is the nature of the research process?	focused	holistic
	known variables	unknown variables
	established guidelines	flexible guidelines
	static design	emergent design
	context-free	context-bound
	dethatched view	personal view
What are the methods of data collection?	representative - large sample	informative - small sample
	standardized instruments	observations
		interviews
		questionnaires
What form of reasoning is used for the analysis?	deductive analysis	inductive
How will the findings be communicated?	numbers	words
	statistics (aggravated data)	narratives (individual quotes)
	scientific style	literary style
	formal voice	informal (personal) voice

Table 2: Characteristics of Quantitative and Qualitative Approaches
Adapted from Leedy & Ormrod (2001). *Practical Research: Planning and Design* (7th ed.).

3.7 Challenges to the Case Study Method

To quote Yin, “The case study has long been (and continues to be) stereotyped as a weak sibling among social science methods.” (Yin, 2003) The opening sentence in the preface indicates a prejudice for attempting a case study research effort. This warning for researchers, more importantly, a researcher using the case study method for a dissertation appears pathological at best. Yin further indicated that, "Do case studies, but do them with the understanding that your method will be challenged from rational (and irrational) perspectives and that the insights resulting from your case studies may be underappreciated At the same time, derive comfort from the observation that, despite the stereotype of case studies as a weak method, case studies continue to be used extensively in social science research – including the traditional disciplines (psychology, sociology, political science, anthropology, history, and economics)…." (Yin, 2003) His candid approach to case study research provides the researcher with sufficient material to approach and mitigate the limitations to be endured in scholarly criticisms and critiques. The limitations are lack of rigor and controlled observations, too long a timeline (for accomplishment), and it creates a massive and unreadable document.

The first criticism, lack of rigor, is due to the inherent problem of bias, which is introduced by the subjectivity (or lack thereof) of the researcher. Then there are the participants, whom the researcher must rely upon to get an understanding of the case. This is a common criticism of case study research. "Quantitative research can also be affected by the bias of the researcher and of the participants: samples can be manipulated, data can be tampered with or purposely excluded, surveys can be poorly constructed and respondents can answer dishonestly." (Patton, 2002) Yin's treatise on case study research specifically focuses on Design and Methods specifically including design procedures and methods to ensure that the case study researcher can systematically approach the case study method. Further, the United States General Accounting Office

(GAO), circa 1990, has an extensive checklist for reviewing case study reports. The use of systematic and traceable methods and formal procedures are strategies to be adopted by the researcher to mitigate criticism, whether deserved or undeserved.

The second criticism, the lack of controlled observations, focuses on the inability of the researcher to make a scientific generalization based on a case study, however, "The short answer is that case studies, like experiments, are generalizable to theoretical propositions and not to populations or universes." (Yin, 2003) In doing case study research, the goal is to expand and generalize analytical theories instead of enumerating frequencies from statistics. "In analytical generalization, the investigator is striving to generalize a particular set of results to some broader theory." (Yin, 2003) The analytic generalization in this case study research is to create a framework from evidence obtained from a collection of case study settings and scenarios of project management to include procedures, schedules, and costs. Analytic generalizations can reveal contextual conditions under which framework-based predictions may be considered to apply, serving to increase the confidence level in the study and framework. "... analytic generalization attempts to show that a theory holds broadly across a wide variety of circumstances, but sometimes it identifies the scope of a theory – that is, the conditions under which it applies." (Firestone, 1993)

The type of generalization used in this research is "analytical generalization," based on the case study, from the empirical results of the case study to theory developed through a systems engineering framework. This generalizable theory is used in literature often, and supported by Yin (2003), Dutton & Dukerich (1991), and Eisenhardt (1989). Yin pro-offers two types of generalizations from case studies: analytical generalization and statistical generalization. Statistical generalization results from an inference made about a population on the basis of empirical data collected about a sample. Yin indicates this as a Level One Inference, recognized since researchers have ready access to quantitative formulas for determining the confidence with which generalizations can be made based on sample size and variation. This is the common method of doing surveys.

Individual case studies "... are to be selected as a laboratory investigator selects the topic of a new experiment. Under these circumstances, the mode of generalization is analytic generalization, in which a previously developed theory is used as a template with which to compare the empirical results of the case study. If two or more cases are shown to support the same theory, replication may be claimed." (Yin, 2003) Further, "The empirical results may be considered yet more potent if two or more cases support the same theory but do not support an equally plausible, rival theory." (Yin, 2003) This type of generalization is indicated as Level-2 Inference. See Figure 11 below.

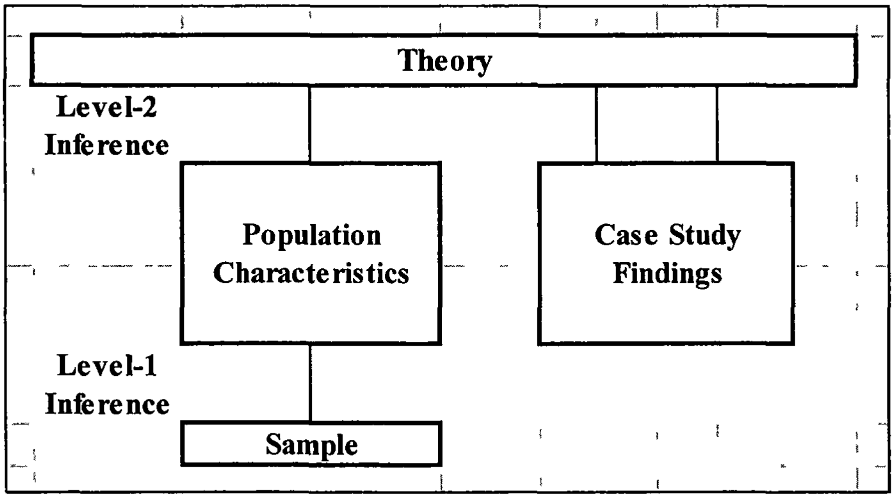


Figure 11: Making Inferences
Adapted from Yin (2003). *Case Study Research: Design and Methods.* (3rd ed.).

Yin (2003) identifies three types of generalizations are: (a) generalizations from population characteristics to theory; (b) generalizations from case study findings to theory: and (c) generalizations from experimental findings to theory. The research developed systems engineering based framework as a template with which to compare empirical results of the case study. The case study included all classes of ships, and used as it supported the theory, so replication may be claimed as each class of ships experienced very similar results.

Criticisms of Case Studies	Mitigation Strategies	Research Design References
Lack of rigor	Formal methodology	Yin (2003)
	Formal data analysis methods	U. S. GAO (1990)
	Guide to achieve quality	Miles & Huberman (1994)
	Case study review checklist	
Little basis for scientific generalization	Analytic generalization to theoretical proposition	Yin (2003)
	Generalizability framework	Lee & Baskerville (2003)
	Level-2 inferences	
Take too long & resulting in a massive unreadable document	Adopt alternative methods to the traditional lengthy narrative	Yin (2003)

Table 3: Case Study Criticisms & Mitigating Strategies
Adapted from Yin (2003). *Case Study Research: Design and Methods.* (3rd ed.).

The results may be considered more potent when viewed from the case study of the entire Navy's ship repair and maintenance program. This case study supported the same theory, and not a rival theory as Yin (2003) had mentioned. Analytic generalization is an important concept for the case study researcher, and is well developed. Lee (2003) indicates the "… criticisms that case studies and qualitative studies are not generalizable would be incorrectly ruling out the generalizability of empirical descriptions to theory. Such criticism could be incorrectly presuming that statistical generalizability is the only form of generalizability and will be included as an essential element of the case study design." (Lee & Baskerville, 2003) This is not so.

Thirdly, Yin mentions that past complaints have been that case study research takes too long and results in massive, unreadable documents. He also indicates that researchers can avoid this outcome and discusses an alternative method to the traditional, lengthy narrative, and how it can be avoided. Table 3 identifies case study criticisms and provides the mitigation strategies used to defend case study weaknesses.

3.8 Challenges to the Survey Interview Method

Controlled observations during interviews can be very important to case study information. "Such an observation may be surprising because of the unusual association between interviews and the survey method." (Yin, 2003) Interviews are considered essential sources of case study method as the interviews will appear to be guided conversations instead of structured queries. "In other words, although you will be pursuing a consistent line of inquiry, your actual stream of questions in a case study interview is likely to be fluid rather than rigid (Rubin & Rubin, 1995)." (Yin, 2003)

Yin further indicated that throughout the interview process, the researcher has two jobs: (a) To follow your own line of inquiry, as reflected by your case study protocol; and

(b) To ask your actual (conversational) questions in an unbiased manner that also serves the needs of your line of inquiry. Consequently, most case study interviews are "… open-ended nature, in which you can ask key respondents about the facts of a matter as well as their opinions about events. In some situations, you may even ask the respondent to propose his or her own insights into certain occurrences and may use such propositions as the basis for further inquiry." (Yin, 2003)

There is a second type of interview, called a focused interview (Meerton, Friske, & Kendall, 1990), in which a respondent is interviewed for a short period of time. "In such cases, the interviews may still remain open-ended and assume a conversational manner, but you are more likely to be following a certain set of questions derived from the case study protocol." (Yin, 2003)

Lastly, there is a third type of interview, which "… entails more structured questions, along the lines of a formal survey. Such a survey could be designed as part of a case study and produce quantitative data as part of the case study evidence." (Yin, 2003) This type of survey would follow the same sampling procedures and instruments as regular surveys and analyzed as such. The difference would be the survey's role in relation to other sources of information obtained in the literature search. Yin indicates that interviews should always be considered verbal reports only. As such, they are subject to the problems of bias, poor recall, and poor and/or inaccurate articulation, and must be corroborated, or better yet triangulated, with information from other sources.

3.8.1 Case Study Method

Why use the case study method? The case study is not often used as the foundation of research, in part to the view that case studies do not meet the level of rigor that is typically expected from scientific research. According to Perry, "Realism is the preferred paradigm for case study research for several reasons. First, case study research areas are usually contemporary and pre-paradigmatic, such as inter-organizational relationships and relationship marketing. That is, the research areas usually require inductive theory building for deduction from already existing principles of a "paradigm" in likely to be difficult where accepted principles and constructs have not been established or are clearly inadequate." (Schultz & Boing, 1994)

In Yin's book, *Case Study Research and Design Methods*, he suggests that "...a case study method to research falls in line with other empirical methods." The quality of the research design can be shown using the measures identified in Table 4 below.

Measure of Design Quality	**Definitions**
Construct Validity	Establishes correct operational measures for the study to ensure that subjective measures do not enter into the data collection.
Internal Validity	Establishes a causal relationship whereby certain conditions are shown to lead to other conditions.
External Validity	Establishes a domain to which a study's findings may be generalized.
Reliability	The auditability and confirmability of the research is demonstrated by ensuring that the research study and data collection procedures can be repeated, with the same results.

Table 4: Measures of Case Study Design Quality
Adapted from Yin (2003). *Case Study Research: Design and Methods.* (3rd ed.).

With regard to the research question form, the "how" and "why" questions previously discussed are more explanatory and will lead to a preference for case studies, histories, and experiments. See Table 5 below.

Strategy	Form of Research Question	Requires Control of Behavioral Events?	Focuses on Contemporary Events?
Experiment	**how, why?**	**Yes**	**Yes**
Survey	**who, what, where, how many, how much?**	**No**	**yes**
Archival analysis	**who, what, where, how many, how much?**	**No**	**Yes/No**
History	**how, why?**	**No**	**No**
Case study	**how, why?**	**No**	**Yes**

Table 5: Relevant Situations for Different Research Strategies
Adapted from Yin (2003). *Case Study Research: Design and Methods.* (3rd ed.).

Once the ranges of strategies were reviewed and the case study method selected, the next condition under consideration is the control the investigator has over the actual events of the phenomenon under study. If an experiment is necessary, the investigator does have varying degrees of control over the independent variables and the phenomena. In the conduct of selecting investigative strategies such as histories or case studies, the investigator does not have control of the phenomena. In determining which of the two options to choose, the final condition is the focus on contemporary events. By its definition, a history is principally concerned with past or prior events. Given the conditions of the dissertation proposed here, a case study design has been selected as the principle research strategy. Lastly, given the theoretical import of historical context, elements of a historical design will obviously be adopted and used where appropriate.

Yin (2003) highlights responses to case study criticisms in his book. Critiques such as lacking rigor, having little basis for scientific generalization, having difficulty in making controlled observations, and taking too long to conduct, and creating too much documentation are addressed. Yin's responses are use of formal methodologies, data analysis, and analytic generalization to theoretic propositions. The challenge is to identify an approach to analysis of case studies that adequately capture the nature of this study and to avoid too broad a study that unnecessarily increases the amount of time devoted to research.

The principle methodology used in this dissertation research is the "case study." (Eisenhardt, 1989; Stake, 1995; Yin, 1981a, 1981b, 1994) More specifically a single case study of a complex system was explanatory in that the goal was to "...pose competing explanations for the same set of events and to indicate how such explanations may apply to other situations." (Yin, 1994, p. 5) The case study approach has the advantage of permitting closer access to the context, participants, and processes and can reflect well the ontological and epistemological assumptions about organizational research and practice.

3.9 Compliance with the Cannons of Science

This section reaffirms the discourse of research methodology by indicating how the ontological, epistemological, methodological, and axiological elements of the researcher's view, combined to produce a paradigm satisfying the accepted criteria for high-quality research. There are four generally accepted criteria for high quality research, compose the Cannons of Science and answer the following questions. (Guba & Lincoln, 1985):

a. Truth Value: How one can establish confidence in the truth of the findings of a particular inquiry for the subjects (respondents) with which, and the context in which, the inquiry was carried out?

b. Applicability: How can one determine the extent to which the findings of a particular inquiry have applicability in other contexts or with other subjects (respondents)?

c. Consistency: How can one determine whether the findings of an inquiry would be repeated if the inquiry were replicated with the same (or similar) subjects (respondents) in the same (or similar) context?

d. Neutrality: How can one establish the degree to which the findings of an inquiry are determined by the subjects (respondents) and conditions of the inquiry and not by the biases, motivations, interests, or perspectives of the inquirer?

Researchers grounded in qualitative and quantitative methods rely on the higher-level Cannons of Science to arrive at well-reasoned conclusions. The design quality concepts, grounded in the Cannons of Science, are discussed in the following paragraphs.

3.9.1 Issues of Validity & Reliability in Case Study Design

Yin (2003) indicates two perspectives for validity: First, internal validity is only a concern for causal (or explanatory) case studies, in which an investigator is trying to determine whether event “x” led to event “y.” Second, the concern over internal validity, for the case study element of the research, may be extended to the broader problem of making inferences. Basically, a case study involves an inference every time an event cannot be directly observed. (Yin, 2003, p. 3) This researcher endeavored to show the plausibility of the research findings against the relationships contained in the research question.

Triangulation, the combination of research techniques, was included as an element of the research design. “The effectiveness of triangulation rests on the premise that the weaknesses in each single method will be compensated by the counter-balancing strengths of another.” (Jick, 1979) Patton (1987) discusses four types of triangulation in doing evaluations – the triangulation: (a) of data sources (data triangulation); (b) among different evaluators (investigator triangulation); (c) of perspectives to the same data set (theory triangulation); and (d) of methods (methodological triangulation). “With data triangulation, the potential problems of construct validity also can be addressed because the multiple sources of evidence essentially provide multiple measures of the same phenomenon.” (Yin, 2003)

Data triangulation was achieved by collecting data from different sources over different time-lines by doing multiple case studies. Data triangulation was invoked by applying systems principles and engineering management techniques to project risk management and life cycle practices.

Method triangulation was included through the use of both qualitative and quantitative methods. The use of multiple methods of triangulation ensures that the research was robust as well as valid.

3.9.2 Construct Validity

Construct validity assures that the researcher establishes sufficient warranted measures for the phenomena, events, structures, of mechanisms under study. (Yin, 1994, p. 34) To establish construct validity, the researcher must: (a) select the changes to be studied in relation to the objectives of the study; and (b) demonstrate that the measures used in the study reflect the changes selected. Yin (1994) recommends three tactics to assure construct validity: triangulation, chain of evidence, and draft review or member checking. (Stake, 1995) All three of these techniques will be used.

3.9.3 External Validity

External validity or generalizability refers to the extent to which the research results may apply to situations beyond the immediate research, which is required for dissertation research. The ability to generalize findings to other cases has been a source of heated dispute between positivists and constructivists. (Phillips & Burbles, 2000; Stake, 1995) To bring clarification to this notion, Yin (1994) makes a case for analytic generalization as opposed to statistical generalization as follows: The external validity problem has been a major barrier in doing case studies. Critics typically state that single cases offer a poor basis for generalizing. However, such critics are implicitly contrasting the situation to survey research, in which a "sample" (if selected correctly) readily generalizes to a larger universe. This analogy to samples and universe is incorrect when dealing with case studies. This is because survey research relies on statistical generalization, whereas case studies (as with experiments) rely on analytical generalization. (Yin, 1994, p. 36)

3.9.4 Consequential Validity

Case study researchers must attend to consequential validity, especially in the domain of performance technology, where findings are often translated into policy decisions, such as this dissertation research. According to Stake (1995, p. 108), consequential validity refers to the responsibility of the researcher to ensure that the process of representing the case has been conducted with the highest degree of rigor. The researcher's burden is to make certain that no unwarranted or invalid descriptions of the case were made that would lessen its esteem. It was the ethical obligation of the researcher that misunderstanding and/or misrepresentation of the case be kept to a minimum, reducing the likelihood of negative consequences as a result of reader interpretations or reactions. (Stake, 1995, p. 109) This case study design has been positioned, the focus is to study and verify the existence of organizational structures and mechanisms at work in the U. S. Navy ship repair and maintenance program. I have explicitly drafted institutional theory for these purposes and find it necessary to establish a priori boundaries or frameworks within which my dissertation can be conducted.

3.9.5 Reliability

The goal of reliability or consistency, is "… whether the study is consistent, reasonably stable over time and across researchers and methods." (Miles & Huberman, 1994) Reliability assures that the protocol of the study can be repeated on the same case giving the same results. This criterion focuses on reducing biases and errors in the research procedures. The objective quality aspect of the evidence for reliability is the ability of a future researcher to follow the same procedures described by the initial researcher, on the same case study, and arrive at the same findings and conclusions. This will ensure the validity and reliability of replication and control elements. Reliability ensures the congruence between the research problem and the data, methods and analysis techniques used by the researcher.

3.9.6 Objectivity

Objectivity or neutrality, addresses "... the issue of whether independent researchers would discover the same phenomena of generate the same constructs in the same or similar settings." (LeCompte & Goetz, 1982) The external reliability of the study was enhanced by addressing four areas recommended by LeCompte & Goetz (1982):

a. The researcher's role in the study was mitigated through the use of an outside expert.

b. "Every concept brought into the study or discovered in the research process was first deemed provisional. Each concept earns its way into the theory by repeatedly being present in interviews, documents, and observations in one form or another – or by being significantly absent." (Corbin & Strauss, 1990)

c. The analytic constructs of the framework were developed as part of a detailed procedure in Chapter VI.

d. The methods of data collection and analysis were supported by precise identification and thorough description of the collection and analysis processes.

The case study element of the research also addressed objectivity in three ways: (a) by utilizing multiple sources of evidence during data collection, providing converging lines of inquiry (data triangulation and internal validity) and multiple measures of the same phenomenon; (b) by establishing a chain-of-evidence during data collection; and (c) having subject matter experts review the draft case study report.

3.9.7 Interview

Interviews were primarily semi-structured with the intent of asking key respondents for the facts as well as for respondents' opinions about events. (Yin, 1994, p. 84) Specifically, the immediate foci of these interviews were to establish the current work and system management design of the Navy's engineering management and practices in ship repair and maintenance. For example, respondents from the stakeholder community were asked to relate their understanding about the facts of the proposed framework as their opinions about its efficacy and impact on organizational command structures and procedures. The questions asked of practicing engineering managers and executives, and subject matter experts, were open-ended and more conversational in nature to draw individual organizational viewpoints and elicit a critique and evaluation of the proposed framework.

Original interviews were conducted in person to establish the Navy's current ship repair and maintenance process. Hand-recorded field notes were taken during these interviews and observations. Results of the individual interviews were not shared with other participants, except as aggregated and interpreted data in drafts of write up notes for the final dissertation. Confidentiality was strictly maintained for all interviews.

3.9.8 Survey

A survey was sent to five subject matter experts, all program managers or senior managers from different commands within the organizational structure of the Navy's ship repair and maintenance program. Replies were received from four of the five SMEs.

3.9.9 Documentation and Archival Records

Documents related to the case study were collected and analyzed to corroborate and augment evidence from other sources. (Yin, 1994, p. 81) Potential sources included Department of Defense and Navy directives, instructions, notices, congressional testimony papers, web pages, PowerPoint presentations at engineering society meetings, newspaper reports, procedural guidelines, and published books, technical journals, and case studies of similar projects. Archival records provided supplementary data and included organizational records of reporting structures and organizational charts.

3.10 Summary

This chapter describes the high-level research and dissertation concept, and provided a detailed description of the research paradigm in terms of the researcher's view and the problem under study. The linking of the researcher's view, the problem under study, and the Cannons of Science is significant as it frames the research study and all influencing elements. Each element of the researcher's perspective is addressed and is explicitly stated, providing the rationale for selecting the mixed-method design. The challenges are presented by this mixed-method design in this research, by applying both deductive and case study elements of the research, and ensuring compliance with the Cannons of Science.

The chapter explicitly addresses the challenges to the deductive and case study elements of the research methodology and shows how each method satisfactorily complies with the Cannons of Science. The generalized methodology and paradigms described in this chapter provide the methodological support for the following chapter. The next chapter will provide an outline of the research design and the specific details of the methods, procedures, and techniques used in the two primary elements of the research.

CHAPTER 4

RESEARCH DESIGN, METHODS, AND PROCEDURE

This chapter discusses the assumptions and rationale that support the selection of the research method, laying out the research design, and concludes with a discussion of the research procedures and techniques of the primary elements of the research.

4.1 The Research Design

The formulation of the research purpose, as articulated in the research questions and propositions, the research plan moved through framework development, data requirements and structure, data collection and analysis, and publication. Other aspects of

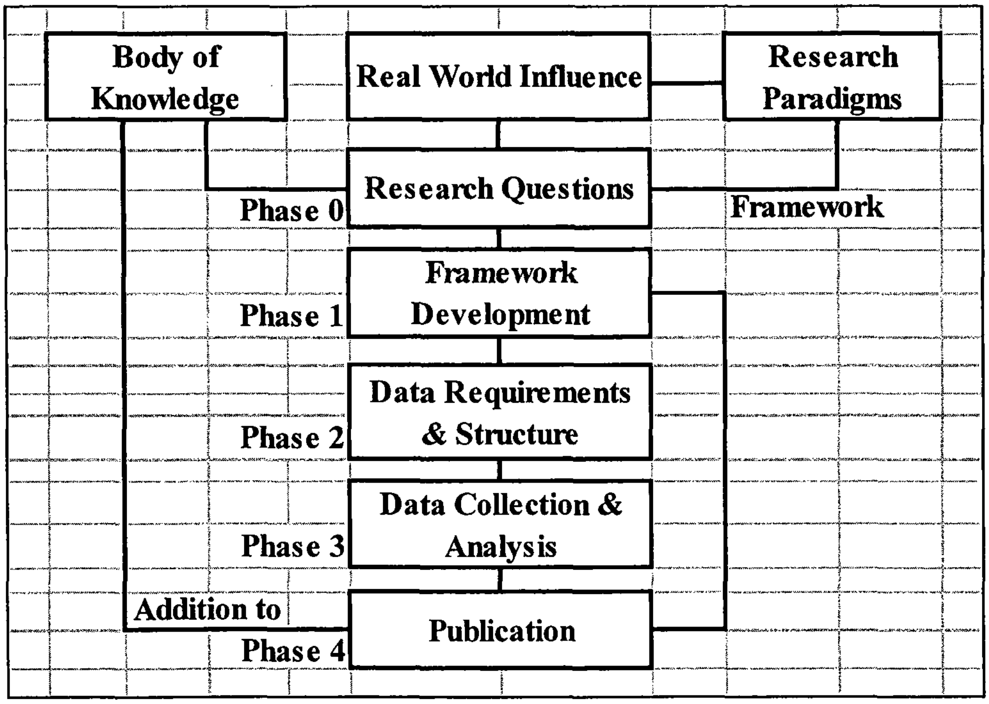


Figure 12: High Level Research Design and Study Phases.

the research plan include the role and influence of scholarly and professional literature, and the Cannons of Science and research paradigm. Figure 12 depicts the high level research design, methodological elements, and study phases. The Research Plan is summarized in Figure 2: Best Practices Steps for a Methodical Study Plan Process. The research was conducted as shown in Figure 13: Research Design and Study.

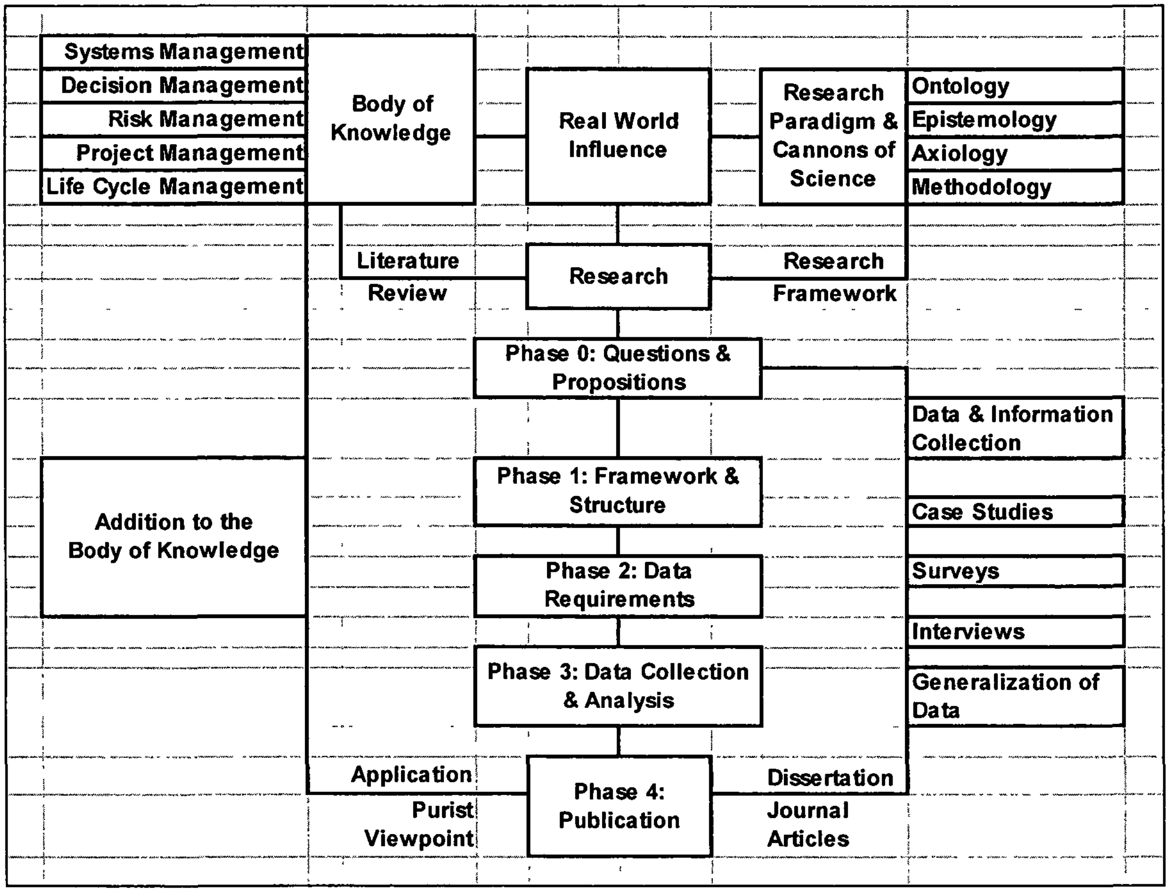


Figure 13: Research Design and Study

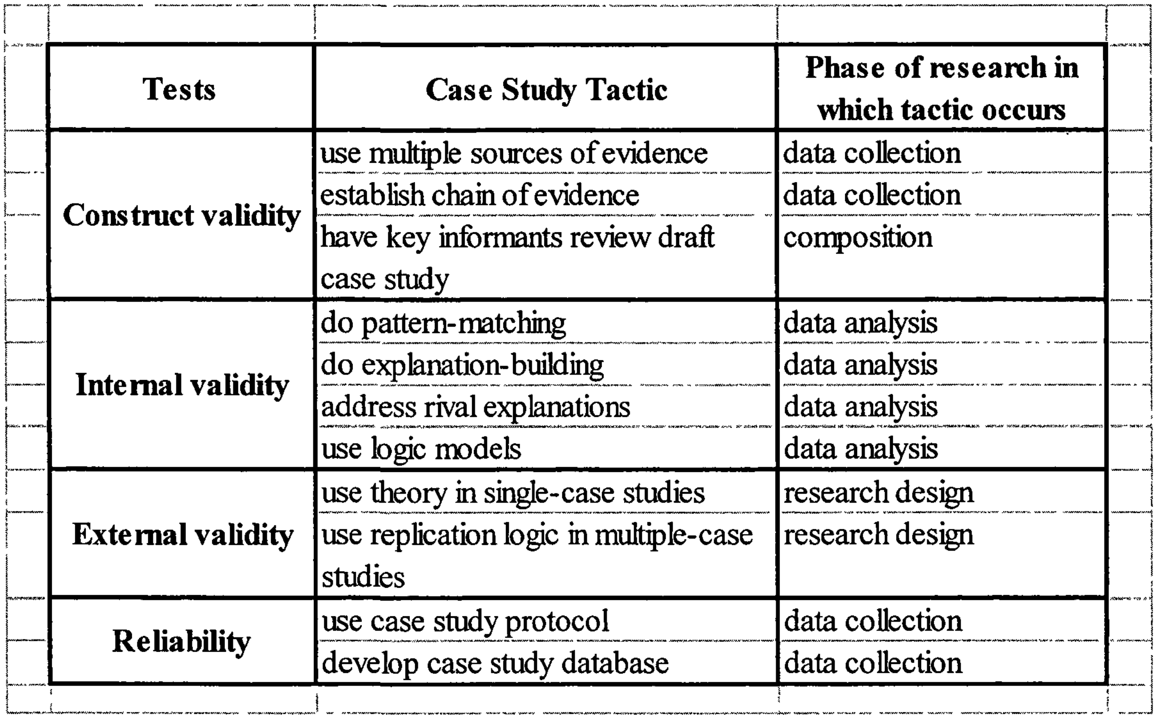
4.1.1 Qualitative Element of the Research Design

Phase 0: Research Questions and Propositions, and defining the research question was the goal of this phase. The research addressed the substance (what) and the form (who, where, why, and how) during the development of the question. Propositions directed the research focus to what was examined within the scope of the study. Specifying the proposition ensured the direction of the research, acting as an anchoring point for determining the relevant research evidence to be included in the study. The propositions also served as a "blueprint" in guiding and determining what data to collect or neglect, and the strategies for determining the method of analyzing the data.

Phase 1: Research Framework Development came from the initial theory was developed from the literature. The initial idea and conception for the holistic, structured, and systemic framework for project risk management using a life-cycle approach for vessel construction, repair and maintenance, and deconstruction was the object of the study. This phase was qualitative and relied on deductive theory building from the governmental literature search to construct the engineering management framework for project risk management and life-cycle assessment. "For case studies, theory development as part of the design phase is essential, whether the ensuing case study's purpose is to develop or test theory." (Yin, 2003) The framework was validated using the quantitative case study method of Yin (2003), described in the next phase of the research design.

Phase 2: Data Requirements and Structure caused the researcher to include all ship classes for use in validating this case study. The criteria utilized for the selection of ships ignored their service life or lengths of operational service. This specific criterion was an important element of the research as the criteria has a direct impact on the ability to make generalizations based on the findings in this or any other study. Once identified, the intrinsic characteristics of the ship inspection, repair and maintenance projects were defined. The high-level characteristics of ship repair and maintenance availabilities over its service life were captured and served as a classification guide and measure of comparison for future research.

In order to avoid being overwhelmed with mountains of data on vessels, an analytic strategy essentially answers the "who, what, when, where, why, and how" questions and what was or was not studied was constructed using the guidelines developed by Miles and Huberman (1994). Yin was very attentive to the following of the four tests as shown in Figure 14: Case Study Tactics of Four Design Tests.



Tests	Case Study Tactic	Phase of research in which tactic occurs
Construct validity	use multiple sources of evidence	data collection
	establish chain of evidence	data collection
	have key informants review draft case study	composition
Internal validity	do pattern-matching	data analysis
	do explanation-building	data analysis
	address rival explanations	data analysis
	use logic models	data analysis
External validity	use theory in single-case studies	research design
	use replication logic in multiple-case studies	research design
Reliability	use case study protocol	data collection
	develop case study database	data collection

Figure 14: Case Study Tactics of Four Design Tests
Adapted from Yin (2003). *Case Study Research: Design and Methods.* (3^{rd} ed.).

The analytic strategy included several specific methods for data collection and analysis related to the engineering management aspect of the project management of naval ships. Throughout the study, particular attention was paid to the data design to ensure that the measures of design quality in Figure 14 were met throughout the study.

Phase 3: Data Collection and Analysis required the identification of the organizational information and command structures was made available from the Navy. This phase of the research design centered on the analysis of the empirical data from all ships in the Navy fleet. "Case studies use a mode of generalization called analytic generalization, which is contrasted against the well known statistical generalization." (Yin, 2003) Here, the case study research will provide an analysis framework (project risk management - life cycle) that was used on real Navy ship's project data for validating the empirical results of the case study. Although each class ship experienced identical availability inconsistencies, these were used to validate the analysis of the case study framework by practicing on program and project managers (subject matter experts) who were interviewed to assist in triangulation. Triangulation, the combination of research techniques is included as a purposeful element of the research design. "The use of multiple methods of triangulation ensured that the research was more robust and valid." (White, 2000) According to Zelditch, methods included, "(1) Data Triangulation, which was achieved by collecting data from different sources over different time-scales using multiple case studies; (2) Theoretical Triangulation, which was invoked by applying systems principles to the discipline of software engineering; and (3) Method Triangulation, which was included through the use of multiple techniques for gathering sources of evidence for the case studies." (Zelditch, 1962) The previous tact provides an additional level of rigor to the technique and further mitigates many criticisms focused on this case study research.

The Phase 4: Publications is the final phase of the research design which is publishing the research findings. This dissertation was the principle publication, with scholarly journal articles yet to be published in order to extend the research findings to a wider audience. This will be accomplished at a later date.

4.1.2 Summary of the Research Design

The research design presented in this section is the compilation of the literature search of the body of knowledge on the subject. The design invoked the Cannons of Science as measures of design quality, conforming to the rules for quantitative data analysis, qualitative analysis, and the rigor of the empirical methods for case study research. Using these systemic methods and formal procedures enabled the strategies to mitigate criticisms leveled at methods, procedures, and techniques enabling this researcher to execute a careful and systematic process. See Figure 10 for the summary of the research design elements.

In summary, the research design presented in this section is a compilation of the established body of knowledge on the subject. The design invoked the Cannons of Science as measures of design quality, conformed with the rules of qualitative analysis (Munck, 1998), followed the procedures for qualitative data analysis (Miles & Huberman, 1994), and invoked the rigor of the empirical method for case study research (Yin, 2003). The use of these systematic methods and formal procedures were strategies to mitigate criticisms leveled at methods, procedures, and techniques as practiced by the researcher to carefully accomplish systematic work. The two major sections that follow will discuss the methods and procedures used in each research element.

4.2 Method for the Theoretical Framework Development

The holistic, structured, and systemic framework for ship repair and maintenance (SR&M) projects developed in this research element not only provides the conceptual basis for understanding the context surrounding any complex system of projects, but supports the development of formal methodologies that can be used by program and project managers to improve project performance. The strength of the framework was grounded upon the theoretical constructs derived from the application of systems theory to the repair and maintenance projects. The methodology is a framework and process for synthesizing theory, practice, and this author's reflection encompassing a vessel's construction, repair, and maintenance life cycle from a project risk management approach to minimize costs and scheduled downtimes. This author, who has a personal interest in the post cold war and Viet Nam eras, reviews the whole Arleigh-Burke class cruiser repair and maintenance case study.

4.2.1 Framework and Theory

The framework, in the context of this research is a type of model that can be applied to carry out a specific purpose, function, or task. "Models may refer to anything from a physical construction in a display case to an abstract set of ideas… a consideration of them will illuminate the structure, interpretation, and development of scientific thinking." (Achinstein, 1965) A scientific model is defined to be, "an interpretive description of a phenomenon (object or process) that facilitates perceptual as well as intellectual access to that phenomenon. 'Description' is intended as a term wide enough to admit various forms of external representations, prepositional or non-propositional. A model is not, however, a description in the trivial sense of a mere phenomenological description of a phenomenon. It gives a description that is an interpretation in that the description goes beyond what 'meets the eye,' e. g. by exploiting a theoretical background that is relevant to interpreting the phenomenon." (Bailer-Jones, 2003)

This definition is important as, "… scientific models are often contrasted with scientific theories." (Nagel, 1951) However, it can be further stated that, "…theories are not about the empirical world in the same concrete sense as models ... models, by their very constitution, are applied to concrete empirical phenomena, whereas theories are not." (Bailer-Jones, 2003) The conceptual model or framework, developed in this research was generated using systems principles, thinking, and practices with project risk management using life cycle boundaries to explain an optimal ship repair and maintenance projects over a 35 year service life. "The use of a framework allows us to express a greater number and larger variety of data and observational facts and - this is crucial – to explain these facts." (Maxwell, 1962)

Further, Pemberton (1993) indicates that a framework can include representations ranging from localized observations to highly abstracted global generalizations. (Pemberton, 1993) Localized observations may include data that can be developed into a model, which may yield theories, and then develop into paradigms of global generalizations. The term representation points to characteristics of scientific models that cannot be captured in an account that exclusively relies on only propositions. (Bailer-Jones, 2003) Further, "…scientific representation is said to be understood as a two-place relationship between statements and the world. A focus on the activity of representing fits comfortably with a model-based understanding of scientific theories." (Giere, 2004) The activity of representing information and data into a model-based framework, that validates or invalidates purported hypotheses or presumed generalizations. Figure 15: Framework Based Theory Development relates the roles of models in theory development.

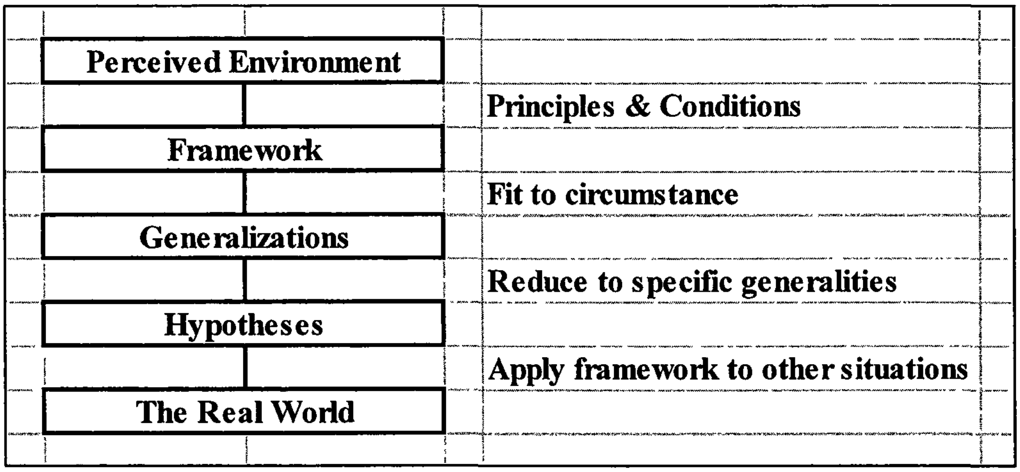


Figure 15: Framework Based Development

4.2.2 Theory Development

In thinking of the term theory, one must define it: "… theory belongs to the family of words that include guess, speculation, supposition, conjecture, proposition, hypothesis, conception, explanation, and model." (Runkel & Runkel, 1984) Karl Weick states that a theory is a "...continuum rather than a dichotomy." (Weick, 1995) Weick further differentiates between theory and theorizing as: "Theory work can take a variety of forms, because theory itself is a continuum, and because most verbally expressed theory leaves tacit some key portions of the originating insight. These considerations suggest that it is tough to judge whether something is a theory or not when only the product itself is examined. What one needs to know, instead, is more about the context in which the product lives. This is the process of theorizing." (Weick, 1995) Weick further indicates that most theories approximate rather than realize the conditions for a strong theory. He goes on to indicate that most products that are "labeled" theory are actually approximate theory, suggesting these approximations take one of four forms described by Merton (1968) and Weick (1975). See Figure 16: Forms of Theory.

Product	**Characteristics**
General Orientation	**Broad framework, specifying types of variables to be accounted, without specifying relationships among variables**
Analysis of Concepts	**Consepts specified and defined but not interrelated**
Poar factum Interpretation	**Ad hoc hypotheses derived from few observations**
Empirical Generalization	**Isolated propositions summarize relationship further interrelationships between two variables, but not attempted**

Figure 16: Forms of Theory

Weick (1989) provides a broad statement about theories, in that they, "...involve so many assumptions and such a mixture of accuracy and inaccuracy that virtually all conjectures and all selection criteria remain plausible and nothing gets rejected or highlighted." (Weick, 1989) He recommends to those building theories to move toward theories of the middle range or toward theories that are nearly theories. Merton (1968) defines theories of the middle range as, "Theories that lie between the minor but necessary working hypotheses that evolve in abundance during day-to-day research and the all-inclusive systematic efforts to develop a unified theory that will explain all the observed uniformities of social behavior, social organization and social change." (Merton, 1968)

Features	**Generalizing Theoretical Strategy**	**Pure Theoretical Strategy**
Objective	Explain and generalize lawful phenomena in open systems	To predict the behavior of lawful phenomena in closed systems
Structure	Systematic, containing ordinary language	Formal, containing no ordinary language
Presentation	Nomothetic universal or statistical generalizations of non-limited spatio-temporal scope, high information content, and describing regular and confirmable observations	Nomothetic statements expressed in universal or statistical form and having high information content (no generalizations) and describe regularities that exist in a theoretically possible world, but not in the actual world
Method	Inductive abstraction	Idealization
Result	Consolidation of theories or data	Cumulation of theory, some which may have engineering applications
Theory Structure	Summarizing information, abstract or general form, that can be used to explain or predict particular empirical cases that fall within the scope of the theory	Describing some idealized state of affairs in a closed system, with laws describing the invariances of the system, and then used for calculating changes in the system when other things are equal.
References	Blau (1970) and Kelly & Thibault (1978)	White (1970) and MacKenzie (1976)

Figure 17: Bourgeois' Theory-Building Format
Adapted from Weick (1989) and Bourgeois (1979).

Merton indicates that middle-range theory is principally used to guide empirical inquiry. The abstractions contained in middle-range theories are close enough to the observed data that they can be incorporated in propositions that can be validated empirically. Weick (1989) indicates that the rationale for moving toward middle-range theories is, "Middle range theories are solutions to problems that contain a limited number of assumptions and considerable accuracy and detail in the problem specification.

Step	Description
Field partitioning	**Clarification of purpose, objectives, questions, and propositions to be answered**
Theory construction method	**Deductive inference: starting with general knowledge and predicts a specific observation**
Literature review	**Selective reading of the writings relevant to one's work**
Construction theory	**Geraeneration of a theory, comparitive analysis of emphirical laws and substantive theories**
Extension theory	**Generalization**
Metaphysical elaboration	**Occasional intuitions that surface into consciousness as one pursues the theory-building task**
Conclusion	**Statements dscribing the theory**

Table 6: Strategies for Theory Construction
Adapted from Freese (1980). *Project Success and Failure: What is Success, What is Failure, and How Can You Improve Your Odds for Success?*

The scope of the problem is also of manageable size. To look for theories of the middle range is to prefigure problems in such a way that a number of opportunities to discover solutions is increased without becoming infinite." (Weick, 1989) Weick (1974) and Bourgeois (1979) both address middle-range theorizing. Weick (1989) is focused on moving (social) systems theory from the category of a grand theory to that in the category of middle-range. Bourgeois (1979) addresses methodological issues on how to organize the theory-building effort in research. Bourgeois (1979) suggests that the middle-range theoretical work includes those presented in Figure 17.

Freese (1980) proposes two independent strategies in constructing theories. Table 6: Strategies for Theory Construction, provides an explanation and prediction of phenomena of real, complex, and contemporary social systems.

4.3 Method for the Framework Validation

The goal of this research is to validate the systemic framework using actual real-world ship repair and maintenance scheduled projects and Expert Judgment by practitioners working for the Navy ship repair and maintenance organizations. These "subject matter experts" are instrumental in determining the validity of the proposed framework. Framework validation is deductive in which the researcher explored whether or not the same relationships existed between the framework attributes and the outcomes by using a different set of evidence, in this instance, case studies, from which the framework was deduced. This was the principle output of phases 2 and 3 in the research design and used in the case study methodology to validate the framework. The criteria utilized for the selection of each of the case studies was an important element of the research as the criteria and have a direct impact on the generalizations that may be drawn from the findings. Once selected, each case study was characterized using a formal project risk management model which served as a guide for future researcher's who may study project risk management ship repair and maintenance life cycle projects using the model.

4.3.1 Theoretical Basis for the Use of Case Studies

Creswell (2003) indicates that case study research is well suited for issues and questions: "...in which the researcher explores in depth a program, an event, an activity, a process, or one or more individuals. The case(s) are bounded by time and activity, and researchers collect detailed information using a variety of data collection procedures over a sustained period of time." (Creswell, 2003)

Leedy and Ormrod (2001) state: "A case study may be especially suitable for learning more about a little known or poorly understood situation. It may also be useful for investigating how an individual or program changes over time, perhaps as the result of certain circumstances or interventions. In either event, it is useful for generating or providing preliminary support for hypotheses." (Leedy & Ormrod, 2001)

Tin (2003) states that a case study is an empirical inquiry that:

- Investigates a contemporary phenomenon within its real-life context especially when the boundaries between the phenomenon and context are not clearly evident.
- Copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result.
- Benefits from the prior development of theoretical propositions to guide data collection and analysis.

Case studies combine data collection methods such as archives, interviews, questionnaires, and observations. The data may be either qualitative or quantitative, or in this case, both. “Case studies are used to provide descriptions, validate theory or generate theory.’ (Eisenhardt, 1989)

A critical assumption in deciding to use a (expert opinion method) (case study method) for validation of the framework was that the boundaries of the case study were not clearly evident at the outset of the research and that no experimental control or manipulation was to be applied or used. Specifically, the researcher had less *a priori* knowledge of what the variables of interest would be, nor how they were to be measured. The distinguishing characteristics of case studies were useful in understanding the strengths of this method.

4.3.2 Case Study Method Overview

The case study method permitted the researcher to gather extensive evidence from the object of the study. “Evidence may come from six sources: documents, archival records, interviews, direct observation, participant-observation, and physical artifacts.” (Yin, 2003) Because the researcher was looking into the past (decades), both direct observation and participant-observation were eliminated as potential data collection methods. The evidence from the case studies were collected, analyzed, and interpreted. The generalization method for case studies was analytic generalization. Analytic generalization involved generalizing to a theory of in this case a framework and a model – not to a population. The case study evidence was used as the basis for the validation of the framework. The real-world behaviors discovered in the case studies rendered judgment with respect to the framework’s ability to predict and optimize performance behaviors based on the frameworks constructs and measurement objects.

The organization of details in the case study aided in the data analysis process. Formal analysis required an analytic strategy, in this case, one that was broad enough to address the conduct analysis at the level of the entire case. The case-based analytic strategy relied on the theoretical propositions and research question(s) that framed the overall research study, forcing them to guide and shape the data collection plan. The analytic strategy contained three sections: (1) formulation; (2) quantitative and qualitative analysis; and (3) interpretation. The analytic strategy was the guide for the remaining processes in the case study method.

The process of collecting the evidence was accomplished through subject matter experts in the complex system of ship repair and maintenance. The researcher collected evidence from historical ship repair and maintenance availabilities. This provided the first section of the analytic strategy, formulation, where the quantitative and qualitative approach used in the analysis was developed. For this research the evidence included documents, archival records, interviews, and physical artifacts. The collection techniques for most of the evidence were very straightforward.

The use of follow up interviews to clarify a previously distributed questionnaire was considered crucial in obtaining the needed data. The reason why was the preponderance of ship repair and maintenance data and information.

The process of organizing, analyzing and interpreting the evidence aided in the interpretation of the collected data and evidence. This process used the second section of the analytic strategy, where quantitative and qualitative analysis served as a guide for the researcher during analysis of the evidence. The overall goal of this process was to derive meaning from the case study evidence in order to reflect any relationships that may emerge.

For this research the dissertation was the principle publication. Secondary publications in the form of an article in a scholarly journal will be sought and produced in order to extend the research findings to a wider audience.

4.4 The Detailed Research Procedure

The detailed research procedure implemented the research design and methods of support. Nagel (1951) stated that: “Every branch of inquiry aiming at general laws concerning empirical subject matter must employ a procedure that, if it is not strictly controlled experimentation, has the essential logical functions of experiment in inquiry. This procedure (we shall call it ‘controlled investigation’) does not require, as does experimentation, either the reproduction at will of the phenomena under study or the overt manipulation of variables, but it closely resembles experimentation in other respects.” (Nagel, 1951) The structure for the research design includes three high-level research elements and five phases. The detailed procedure includes steps and milestones. A step is a specific technique or procedure, and is the third and lowest level of the research design, supporting a phase. A milestone marks a significant point in time when a specific deliverable or decision must be made.

4.4.1 Introduction to the Qualitative Procedure

The first steps in the procedure developed the framework using Miles and Huberman (1994). The method was accomplished in a series of well-defined processes. Figure 18: Project Management Process shows the overall structure for the qualitative research element. The researcher used modern qualitative data collection and analysis techniques which were the basis for the research procedure. This followed the pragmatic practice of combining techniques to obtain the desired results recommended by Creswell (2003).

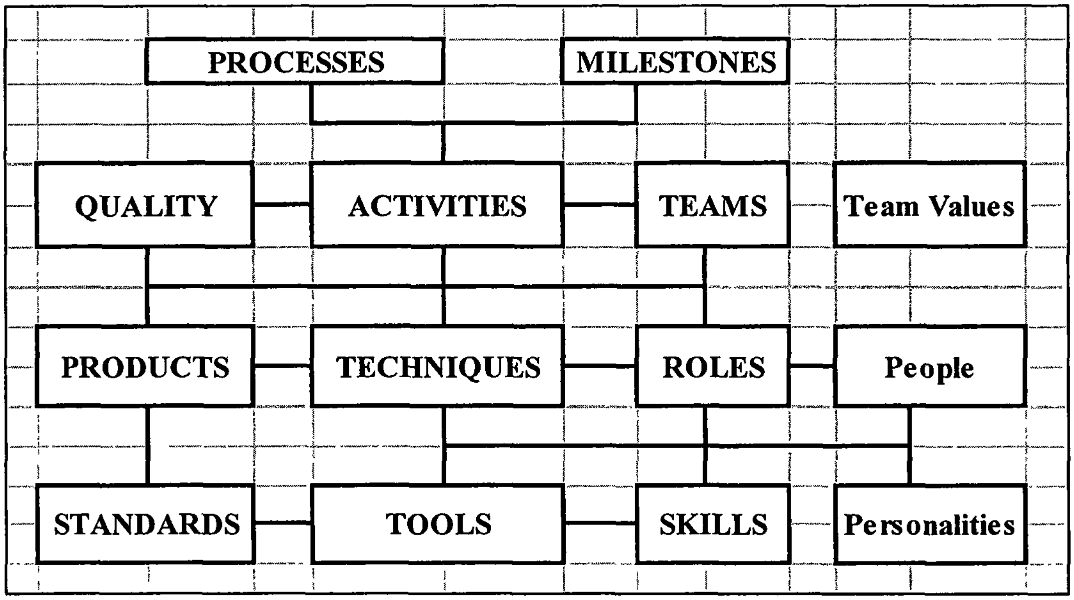


Figure 18: Project Management Process
Adapted from Cockburn (2000). *Selecting a Project's Methodology, Humans and Technology,* IEEE Software, July/August 2000.

The following sections will discuss the detailed steps taken during the qualitative element of the research. Phase 0 was not included because the associated step and milestone were discussed in Chapter 1.

4.4.2 Literature Database

The goal of the first phase was the assembly, synthesis, and verification of empirical facts for the induction. This started when the researcher observed the phenomena under study and carefully described what had been observed. This focused the research effort by establishing boundaries that both constrained and enabled the induction method. This mental operation focused on an idea or conception supplied by the researcher. This was accomplished in three distinct steps.

The researcher's process was to begin as a discoverer bringing an idea to bear to formulate knowledge based on academic training and real-world experience. The idea was stated as a proposal of an observed scientific problem, formed in a statement of a set of known facts. Freese (1980) discusses theory construction as "... typically begins with empirically grounded, systemic discourse expressed in an ordinary language." (Freese, 1980)

The observation and collection of facts includes the literature review and the sifting of information presented in scholarly journals as well as other sources. See Appendix B. "Reviewing relevant literature enhances traditional induction by helping theorists link emerging theory to extent work recognizing the influence of their own theoretical inclinations." (Lewis & Grimes, 1999) The content of the research created a boundary for the research which was clearly stated. The schema for the literature review, the scholarly journals included in the review, and the resulting synthesis were within the established boundary, ensuring a range of ideas, concepts and theories. The worldview formed from the researcher's conceptual perspective acted as a filter in deciding the inclusion or exclusion of data, information, and journal articles. The researcher made the decision to include or exclude particular elements of the observations based on their importance and relevance. This process resulted in "... facts that are both theory-laden and value-laden." (Guba & Lincoln, 1994) The researcher was tasked with ensuring that the research boundaries and underlying assumptions were made explicit as the outputs of this step were the principle factual information and data sources for the first element of the research. During this step the empirical data was documented and measured in qualitatively (words) and quantitatively (numbers) using formal methods and techniques developed to address the collection and analysis of data and information. Of particular importance is the framework for the collection of data (Miles & Huberman, 1994). This construct specified who and what was not studied and developed the formal relationships that created the boundary of data collection. Two activities occurred during this process, data reduction and data display. Seaman (1999) describes several qualitative methods for data collection and analysis and how they may be incorporated into empirical studies. Munck's (1998) principle element was the concept of a research cycle and methodological rules for qualitative analysis. Munck was very specific in framing questions to ensure that the data collected was reputable, reliable, and valid. Using this methodology mitigates many criticisms involving data collection in a qualitative research situation ensuring that the validity of collected data, and the distinction between internal validity and external validity is described in the methodology.

In the verification of real-world facts, a feedback loop is needed to verify that the literature review captured all of the relevant information. The information of the literature review was the source of empirical data for colligation, and provided the range of ideas, concepts, and theories. The observation and collection of empirical facts, "...has a direct affect on the validity of the inductivity predicated allegory which depends primarily on the quality of the data base from which the inductive inferences were derived." (Sutherland, 1973) The researcher sought outside expertise in order to ensure that the information selected by the researcher was adequate enough to provide a firm foundation. The means for gathering outside expertise involves three factors according to Meyers & Booker (2001): (1) selecting experts according to particular criteria; (2) designing elicitation methods; and (3) specifying the mode in which the expert is to respond. The formal procedure for verifying real-world facts was addressed in this manner. The selection of the expert was governed by professional position, professional qualifications, and the availability and accessibility of each expert. The expert satisfies the qualifications needed, such as education, experience, reputation, and publications. The deliverable at the end of this phase was a database of synthesized literature sources used for the development of the research framework.

The goal of phase 2 is the development of the structured, systemic framework for the optimized inspection, repair, and maintenance over a ship's service life or "life cycle." In gathering facts from the literature search, the term fact must be defined. Wherwell (1858) stated that, "what facts are to be made the materials of Science, perhaps the answer which we should most commonly receive would be, that they must be True Facts, as distinguished from any mere inferences or opinions of our own." (Whewell, 1858) A further delineation regarding data is "...a distinction is made between hard and soft data, according to whether they are purely observational or contain an inferential element." (A. Kaplan, 1964) It has been said that observation is already cognition and that observed (collected) facts imply more than 'just facts.' As the researcher makes observations, he/she will interpret observables and classify the data without knowingly doing so, making logical inferences. In Coombs' theory of data (1964) he indicates how the researcher's interpretation of observables and classification of data can lead to logical inferences which can impact research. He uses three phases to address the above-mentioned research concerns: Phase 1 - the decision as to what to observe; Phase 2 – the mapping of recorded observations into data; and Phase 3 – the choice of a framework for making inferences from the data. To summarize Coombs' thesis, was that data are recorded observations as well, and already subject to analysis.

During this step, this researcher complied with what Whewell purports, which is that the discoverer must strive to decompose the complex facts identified in the real-world into elementary facts. Secondly, this is where empirical facts synthesized from the literature review are broken down into specific elements. Lastly, this is the phase where information was transformed to data, data into categories, and categories into properties for the framework dimensions.

In support of this step, research analysis includes coding. "Coding is analysis...This part of analysis involves how you differentiate and combine the data you have retrieved and the reflections you make about this information. Codes are tags or labels for assigning units of meaning to the descriptive or inferential information compiled during the research. Codes usually are attached to chunks of varying size – words, phrases, sentences, or whole paragraphs, connected or unconnected to a specific setting." (Miles & Huberman, 1994) The synthesis process conducted in the literature review resulting in a number of information threads, populating the document database with appropriate factual ideas, concepts, and theories, which acted as the empirical data for colligation.

The empirical data of the observed phenomena were classified into relevant categories. The initial classification schema was defined along natural attributes of the phenomena.

This schema was used to organize and simplify the data properties and dimensions into groupings with possible relationships between and among observed phenomena. The idea resulting from the groupings served to form the basis for the development of the framework. A classification schema was used to simplify and organize the data properties and dimensions into information groupings composed of possible relationships between the observed phenomena and the idea that served as the basis for the development of the framework. Eisenhardt (1989) recommends using a systemic series of analyses to help manage the researcher's limited information-processing capability in breaking down, interpreting, and conceptualizing large amounts of data.

The classification of facts was based on a systemic set of relationships. Strauss & Corbin (1998) indicate systemic relationships as:

- Properties: Characteristics of a category, the delineation of which defines and gives it meaning.
- Dimensions: The range along which general properties of a category vary, giving specification to a category and variation to the theory.
- Subcategories: Concepts that pertain to a category, giving it a further clarification and specification.
- Categories: Concepts that stand for phenomena.
- Concepts: The building blocks of theory.
- Phenomena: Central ideas in the data presented as concepts.

For this research, “properties and dimensions refer to those of processes and not to those of a person, group or organization; as the properties and dimensions of a process were more relevant to studies aiming at theoretical conceptualization.” (Glaser, 1978)

In summary, the properties and categories discovered in the empirical data were the building blocks of the emerging concepts. As the categories became more inter-related, a theoretical framework was fashioned. Throughout this process, steps were made to ensure that the methodology for data collection was: “...replicable, reliable, valid, without bias, and within the measurement tolerance and certainty.” (Munck, 1998) This process assists in mitigating criticism surrounding the data classification for the qualitative element of this research.

There were infinite numbers of conceptualizations describing the collected facts. This required the researcher to recognize and explicitly determine data attributes, and their magnitudes correlated most strongly with the patterns in the outcomes of interest (Carlile & Christensen, 2005). To reduce the number of possible concepts, Mullins (1974) constructed a system for culling and evaluating collected facts. His analysis uses four basic properties which summarizes all types of relations for relating concepts within a theory:

- Associations: two concepts joined and the juxtaposition is asserted in a proposition.
- Asymmetry: an assertion of the relation in one sentence is not equivalent to asserting that relation in an opposite order.

- Quantification has two elements: sign (for concepts that are divided into dichotomies indicating which category of one concept varies with that of another); and effect (the size of the effect of one concept on another, either verbally or in numerical form)
- Interdependence: the dependence of one relation for some of its properties on other relations.

Mullins includes a procedure by which the researcher may reduce the number of relational statements among the concepts in order to produce a theory which can logically and empirically be evaluated. The literature research revealed a number of concepts, each with varying degrees of validity and reliability. The researcher determined which had the greatest worth. Mullins includes a procedure by which a researcher may reduce the number of relational statements among the concepts in order to produce a theory which can be logically and empirically evaluated. The three essential steps are:

- The combination of properties from different statements to give a more comprehensive statement, or build separate models to be verified against data if specific properties contradict each other.
- Develop an estimate of the effect of each concept on each other.
- Creation of a matrix which uses the concepts in the set of relations as the rows and columns in the table.

The creative and intellectual work, according to Mintzberg (1979) is, "...detective work, the tracking down of patterns, consistencies." He goes on further to say, "there is no one-to-one correspondence between data and theory." (Mintzberg, 1979) Selye (1964) indicated researchers may get, " … an intuitive flash, the hunch, which though inspired by the previous steps cannot be deduced from them by the application of formal logic." (Selye, 1964) This is where the researcher developed the structured framework for project risk management of complex systems.

The goal of the third phase was the verification that the structured systemic framework containing the requisite procedures and authority that it was intended to change and affect. This step permits the theoretical framework to be verified. Wherwell's verification criteria are "…prediction, consilience, and coherence." (Snyder, 1994, p. 797) The specific characteristics of the verification criteria are as follows:

Prediction, simply put, "…the use of the model [framework] is to generate predictions or to make truth statements about the model [framework] in operation." (Dublin, 1978, p. 163) A framework is characterized by its components, units, interactions, boundaries, and system states. These characteristics establish the range that the framework may operate and may realistically explain past·as well as future behaviors. Hempel and Oppenheim stated, "...that an explanation is not fully adequate unless its explanans [the explanatory premises] if taken account of in time, could have served as a basis for predicting the phenomenon under consideration." (Hempel & Oppenheim, 1948, p. 138) They also note that Reichenbach (1944) established the logical similarity between explanation and prediction, where one is directed toward past occurrences and the other towards future ones. This statement indicates that there is no difference between explanation and prediction in the context of a framework. From an operational perspective, the best measure for the framework may be its relevance. A "useful" framework will predict relationships, without causal assumptions.

Consilience, provides the unity of knowledge, and by Wilson (1998) in an attempt to bridge the culture gap between the sciences and the humanities. Whewell stated that "...the evidence in favor [sic]...is of a much higher and more forcible character when it enables us to explain and determine [i.e., predict] cases of a kind different from those which were contemplated ..." (Whewell, 1858, p. 87-88), He also abdicated focusing research efforts towards "the advancement of science." (Whewell, 1847) The framework was judged on its ability to logically apply the empirical descriptions in the systems-based literature to a framework that addressed project risk management and life-cycle assessment to the repair and maintenance of ship performance.

Coherence, was accomplished by Whewell's test of a theory's truth was coherent. He claimed that "...the system becomes more coherent as it is further extended. The elements which we require for explaining are class of facts are already contained in our system...In false theories, the contrary is the case." (Whewell, 1858, p. 91) In this case, coherence occurs when a framework is able to be applied to a new or different class of phenomena without changes or modifications to the existing framework. Whewell viewed coherence as a "special type of consilience" that happened over time, stating that "...consilience and coherence are, in fact, hardly different." (Whewell, 1858, p. 95) This researcher did not have the luxury of evaluating the framework over any meaningful length of time, the field expediency method of simplicity was used as a measure for coherence. In summary, the completed framework was verified against the previously mentioned criteria.

External verification is designed as a formal check of the completed framework, prior to it being validated through case studies and interviews with senior personnel in the Navy's ship repair and maintenance program.

4.4.2 Introduction to the Qualitative Reporting Procedure

This element of the research was centered on analysis of the empirical data from the case studies and comparison with the qualitatively derived framework/model developed in the first element. The following sections will discuss the phases and detail the steps taken during the quantitative and reporting elements of the research.

For the selection of the case study, the step required the researcher to compile and review ship repair and maintenance availabilities for inclusion in the case study. Analytic generalization involved generalizing to a theory or in this case, a framework and was based on validating the framework-driven behaviors with evidence collected in a variety of settings in the case studies.

4.4.3 Procedure for Case Study Validation

The goal of this phase of the research was the selection and structure of the data required to validate the framework developed in Phase 3. This phase was supported by two independent steps that selected and characterized the case studies.

The first action in the selection process was to conduct a review of the project risk literature in search of a standard typology. A survey of the major project management texts to include INCOSE documents and the latest version of PMBOK documents made no mention of project risk management and life-cycle assessment type, typology, or taxonomy. However, a large number of project management and risk management characteristics were considered when developing risk estimates for optimally scheduling jobs and/or projects.

The second action in the selection process was to search the general project management literature in search of a standard project typology.

The third action in the selection process was to search governmental project management, program management, and executive management literature in search of a standard project typology.

The final action was the description of the proposed framework. In this phase the case study data were collected and analyzed and a judgment with respect to the applicability of the framework was made.

4.4.4 Developing the Analytic Strategy

Formal analysis required an analytic strategy that was broad enough to address the conduct of analysis at the level of the whole case. The uniqueness of the analytic strategy is influenced by the following factors:

- Problem definition
- Case Study Boundaries
- Stakeholders
- Data Collection
- Analysis Forms and Techniques
- Researcher

- Resource Constraints

The analytic strategy developed in this step served as the framework for the next three steps of the case study method and acted as the protocol for the study. “The protocol is a major way of increasing the reliability of case study research and is intended to guide the investigator in carrying out the data collection.” (Yin, 2003)

The researcher collected evidence from senior managers who are deemed subject matter experts with the complex system of ship repair and maintenance processes. This was addressed by the first section of the analytic strategy formulation, where the qualitative and quantitative approach used in the analysis was developed. Formulation involved (1) setting boundaries to define the aspects of the cases studied and (2) the creation of a frame to help uncover, confirm, and qualify the basic processes and constructs that served as the foundation of the research.

Using multiple sources of evidence from subject matter experts in different commands who are involved in the ship repair and maintenance program enabled this researcher to include a broader range of issues than that found with a single data collection method or perspective. Another important advantage is that the evidence formed converging lines of inquiry in a process called triangulation. Denzin (1971) stated that “… triangulation forces the observer to combine multiple data sources, research methods, and theoretical schemes in the inspection and analysis of behavioral specimens.” (Denzin, 1971) Additionally, White (2000) and Denzin (1971) propose three methods of triangulation:

- Data Triangulation: This is achieved by collecting data from different sources over different time-scales.

- Method Triangulation: This was accomplished by using multiple methods. Zelditch (1962) calls this method the between-method triangulation

- Theoretical Triangulation: This was used by applying the theory of one academic discipline to the research with another discipline. Here the researcher used systems principles to project risk management of ship repair and maintenance scheduling. This real triangulation process took place, with facts or phenomena supported by more than one source of evidence. Using triangulation helped to establish key measures of case-study design quality, resulting in construct validity.

Collecting documents, records, and physical artifacts from ship repair and maintenance naval procedures and ship availability projects as case studies was a straightforward process. All documents, records, and artifacts were stored in the case study database created in the next step. The type of evidence collected in the case study research was unique and warranted further examination and study.

The creation of a case study database that is traceable and reproducible is crucial to research. Yin (2003) states that it is absolutely essential to separate the case study materials into two distinctly independent collections:

- Collected Evidence: All documents, archival records, physical artifacts, and researcher's notes.

- Investigators Conclusions: The formal conclusions from the case studies, including the analysis and interpretation of the case study evidence contained in the database and the final report of the findings.

Maintenance of the chain of evidence also requires due care and consideration must be given to the case study evidence in a manner that an external observer would be able to follow the derivation of evidence, ranging from the initial research question to the ultimate conclusions of the case study. "Such a principle is based on a notion similar to that used in forensic investigations." (Yin, 2003) The ability to clearly demonstrate the chain of evidence, with clear cross-referencing between collected evidence, methodological procedures, and conclusions establishes one key measure of case study design quality and construct validity.

4.4.5 Analysis of Case Study Evidence

According to Yin, the analysis of case study evidence is one of the least developed and most difficult aspects of doing case studies. This step indicates how the researcher analyzed the evidence collected in the previous step. This is addressed by the second section of the analytic strategy for qualitative and quantitative analysis. Yin (2003) provides the following warning to case study researchers: "The analysis of the case study evidence is one of the least developed and most difficult aspects of doing case studies....unlike statistical analysis, there are few fixed formulas or cookbook recipes to guide the novice (one of the few texts providing useful advice is Miles and Huberman, (1994). (Yin, 2003, p. 75)

The second section of the analytic strategy was used to guide the researcher in analyzing the evidence. In this step, both qualitative and quantitative analysis methods were applied to the decision alternatives presented within the problem domain.

Relying on theoretical propositions is Yin's first and most preferred strategy, which is to follow the theoretical propositions that led to the researcher's case study. The original objectives and design of the case study are based on this proposition, reflecting the research questions, review of the literature, reinforcing the original propositions. The propositions shaped the data collection plan and prioritized the analytic strategy. The propositions provided theoretical orientation guiding the case analysis. The proposition focuses attention on certain data while ignoring other data. The proposition also helped to organize the entire case study and to define alternative explanations to be examined. Theoretical propositions about causal relations helps to answer the 'how' and 'why' questions, and are very useful in guiding the case study analysis.

4.4.6 Interpretation of Case Study Evidence

In this step, the researcher interpreted the evidence collected in the previous step. For this research, the case study will confirm or negate the proposed framework's ability to improve the project-risk management and life-cycle assessment techniques to improve the ship repair and maintenance process and performance outcome.

The researcher formally interpreted the analysis results and the implication for the framework/model. This step was subjective but was constrained by the structure for the inquiry, the framework, and the general deductive method. The interpreted section of the general analytic strategy was selected from the three interpretive strategies recommended by Yin (2003) which relies upon theoretical propositions. According to Yin, this is the most preferred strategy as "the original objectives and design of the case study presumably were based on such propositions, which in turn reflected a set of research questions, reviews of the literature, and new hypotheses or propositions." (Yin, 2003)

In explanation building, the researcher explained the phenomenon by stipulating a presumed set of causal links. "In most studies, the links may be complex and difficult to measure in any precise manner." (Yin, 2003) Yin warned that explanation building case studies are reported in narrative form that they lack precision. Therefore, "...the better case studies are the ones in which the explanations have reflected some theoretically significant propositions." (Yin, 2003)

The researcher made an initial statement about the framework/model's ability to optimize ship repair and maintenance projects. This was a subjective analysis based on project risk management systems-based theoretical construction to compare findings of an initial case against the initial statement. The researcher compared the findings of the case against the research purpose, objectives, and questions as substantiated in the framework. This involved matching the empirical data from the case study against the measured objects in the framework. The case study evidence aligned with the framework/model provided the basis for a sound objective analysis.

The final products for this phase were the interpretation of the case study and the implications for the framework.

4.4.7 Reporting the Case Study

The goal of this phase was to report the findings in the dissertation and the preservation of the evidentiary data for use in a follow-on article in a scholarly journal.

This step brought the results and findings to closure in the dissertation. The interpretation step used explanation building as a primary technique, thus a narrative style was used to explain the resulting case study description. Patton (1987) provides an overview of the case study report: “The case study is a readable, descriptive picture of a person or program that makes accessible to the reader all the information necessary to understand that person or program. The case study is presented either chronologically or thematically (sometimes both). The case study presents a holistic portrayal or program. (Patton, 1987) Yin (2003) addresses four concerns related to the composition and reporting requirements for case studies:

1. Targeting Case Study Reports

The researcher considered the likely audience as the starting point when composing the case study. This research has as its principle audience, the dissertation committee and academic colleagues. The wider secondary audience will be the ship repair and maintenance community with a focus on project risk management and decision making.

2. Case Study Reports as Part of Larger Multi-Method Studies

This research has included the deductively developed holistic, structured, systemic framework/model for project risk management of ship repair and maintenance scheduling. The framework served as a systems-based lens through which ship availability repair and maintenance jobs and projects were viewed. The case study was used to analyze and validate the framework.

3. Illustrative Structures for Case Study Composition

The organization of the report, including the format dictated by the dissertation and journal article were influential in preparing a case study. This research used a theory building structure in which the content followed the logic that produced the statement about the utility of the holistic, structured, systemic framework for project risk management of ship repair and maintenance scheduling.

4. Procedures in Doing a Case Study Report

There were three important procedures pertaining to case studies, considered by this researcher:

a. The first procedure encouraged the case study researcher to start writing as soon as practicable.

b. The second procedure concerned identifying the case and the participants. Were they to be identified or remain anonymous?

c. The third procedure concerned what constitutes an exemplary case study?

Yin (2003) provides five general characteristics of exemplary case studies: (1) must be significant; (2) must be complete; (3) must consider sufficient alternatives; (4) must display sufficient evidence; and (5) must be composed in an engaging manner. The final products for this phase are the completed case study and its implications for the framework/model.

4.5 Summary

This chapter has provided an outline of the research design and the specific details for the methods, procedures, and techniques used in the primary elements of the research.

The specific procedures and techniques in this chapter provided the formal steps used to obtain the research results described in the following chapter.

The detailed steps used in the development of the framework were of particular import. The internal validity, reliability, and objectivity of the research were supported by the use of a Subject Matter Expert (SME).

The next chapter will explicitly state the data sources and data collection methods used in the research, along with any unique procedures and techniques that are used in the development and validation of the structured systemic framework for project risk management and life cycle schedule for ship repair and maintenance, in order to optimize a ship's 35 year service life and to reduce costs.

CHAPTER 5

RESEARCH RESULTS

This chapter presents the results of the research into two sections. The first section is the development of the framework and explains the results of the framework construction. The second section is the Case Study Validation of the Framework. This section addresses the results of the application of the framework to real- world ship repair and maintenance.

5.1 The Framework Process

5.1.1 Collection and Verification of Facts

The literature review of journal articles, books, and many governmental directives, handbooks, instructions, and notices provided the empirical facts required for development of the literature based structured and systemic framework. The synthesized literature ensured that the researcher was exposed to a range of ideas, concepts, and theories from the extant literature, and enhanced this research by formally linking the emerging framework to the extant work. The information synthesized in the literature review had a direct effect on and was the primary source of empirical data for the creation of the framework. The researcher employed outside experts to verify that the literature review had captured all of the relevant information in order to directly address content validity. The researcher revised the original literature review to include additional governmental articles, organizational documents, and changes to the Navy's SR&M program as recommended by outside experts.

5.1.2 Decomposition of Facts

Documents were scrutinized for commonalities that reflected categories or themes within the data. The researcher used analytical coding as the process to interpret and reflect on the meaning of the data to arrive at new ideas and categories. This process entailed gathering material to be analyzed and reviewed, from a growing understanding of the categories in the data.

5.1.3 Classification of Information Groupings

The facts in the articles and governmental instructions and directives were subjected to Qualitative Data Analysis (QDA) techniques. "...the researcher sorts and sifts them, searching for types, classes, sequences, processes, patterns or wholes. The aim of this process is to assemble or reconstruct the data in a meaningful or comprehensible fashion." (Jorgensen, 1989) A line-by-line analysis of each document into information groupings that proposed possible relationships between the data sources and the conception about the relationship between the SR&M process as designed and practiced, and the system as proposed from the academic literature research. The information collected from sources was contained in informational groupings, which uniquely reduced the large set of data into sub-categories and which was vital for constructing the SR&M framework. The final inter-related data structure contained all of the information used to build the theory underlying the framework.

The most intellectually challenging step in the development of the framework was reducing the information and establishing relationships among the data collected. The reduction of the twenty-three sub-categories into five categories and thee concepts for inclusion in the underlying theory for the framework and model required comprehensive concentration. There were many relevant factors in the sub-categories with others adding little value. This process was crucial in selecting the essential data to be carried forward and included into concepts and theory for the framework and model. Essential data were: (a) could be related to other categories; (b) appeared frequently; (c) were related in a logical manner requiring little force fitting; and (d) that which could explain and/or support the relevant elements of the concept. The criteria to control subcategory and category creation required ranges of variability that was possible through tracking and recognizing patterns and consistencies in the data.

The researcher chose on a systematic set of hierarchical relationships with five elements: (a) empirical information; (b) subcategories or information groupings; (c) categories; (d) concepts; and (e) the theory for the framework. The researcher began with thirty subcategories and grouped the data sources into five categories. The five categories were clustered into three basic concepts: foundation, structure, and elements. A foundation is a concept that is provided a basis for the theoretical framework founded on recognizable system principles. A structure provides the concept to enable a theoretical framework to be synthesized from systemic methodologies and systemic-based models. Elements provide the functions and processes for the theoretical framework and model for ship repair and maintenance optimization using project risk based management. The hierarchical relationship between subcategories, categories, and concepts is presented in Figure 19.

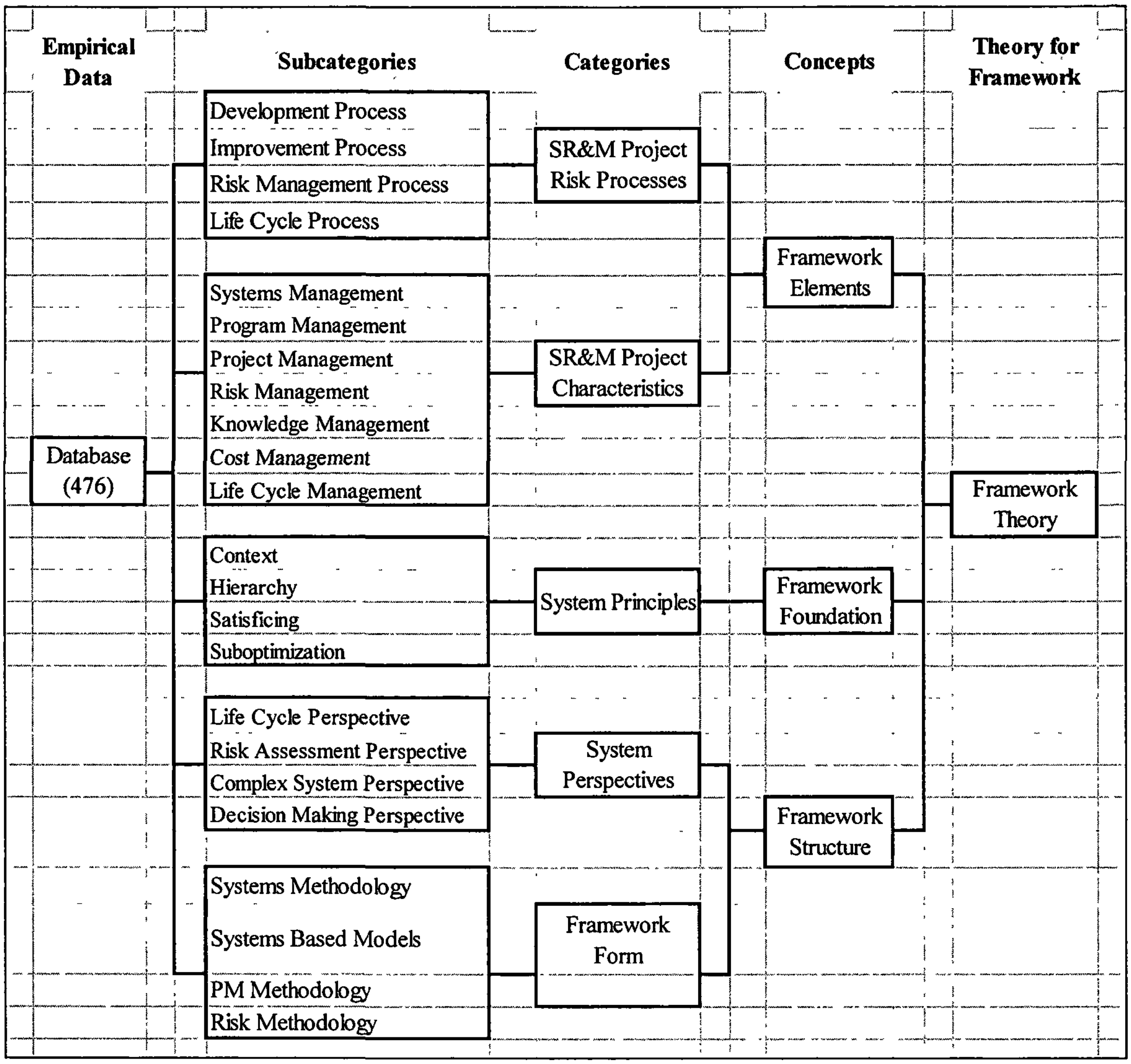


Figure 19: Data Subcategories and Hierarchy

5.1.4 Synthesis of Concepts

The development of the underlying theory for the framework required the researcher to select essential data from the concepts. Figure 20 indicates the five categories and three concepts, which were logically used to produce the framework.

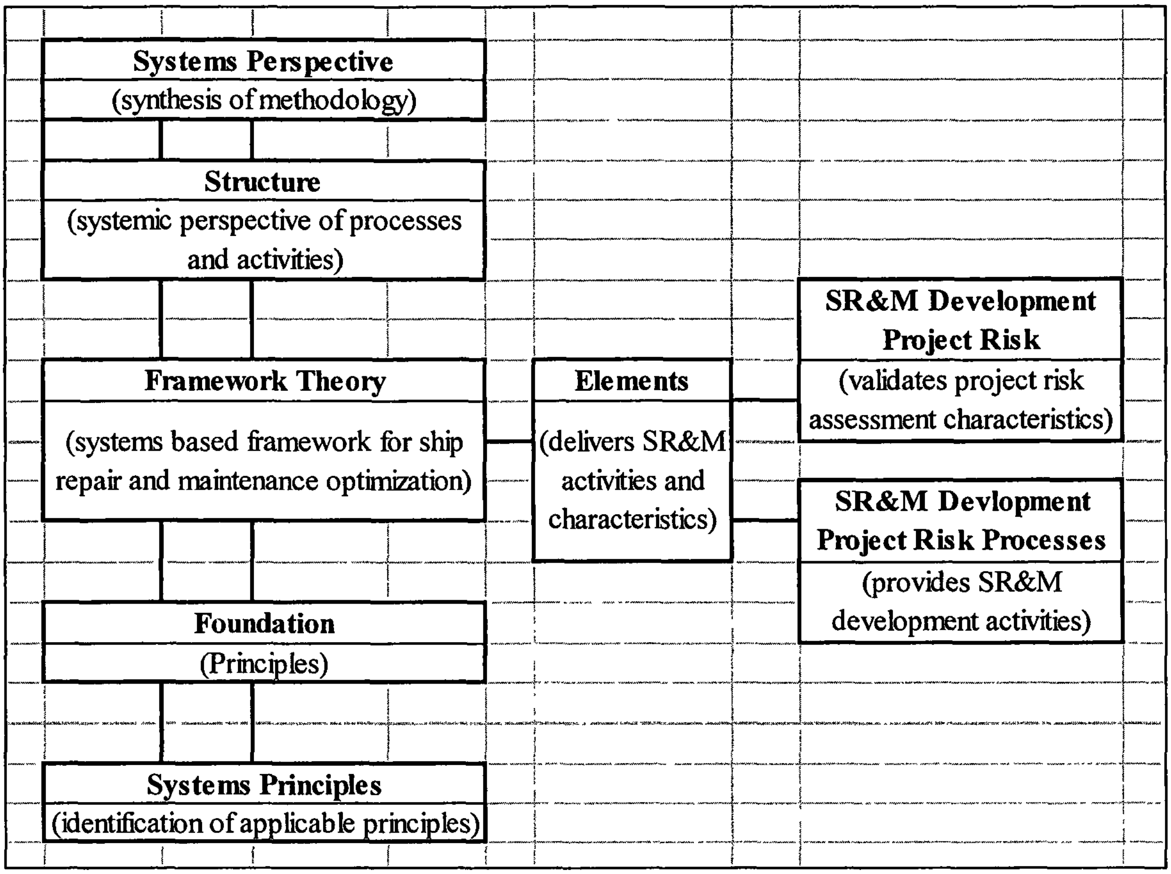


Figure 20: Framework Influences

The question, what is the relevance of systems life cycle to the problem must be addressed. All navy ships are highly complex system of systems, and the scheduling of inspections, repair, and maintenance of systems, subsystems, and their components from a ship could benefit from the systems life-cycle approach. If the Navy determines a ship's service life to be 35 years, then this time period would necessarily mandate that periodic repair and maintenance projects and/or jobs be accomplished according to a definite periodicity. For any SR&M project or job to be deferred for any reason, there would be an inherent increase in the risk of failure or reduced capability of the ship in the future years of its service life.

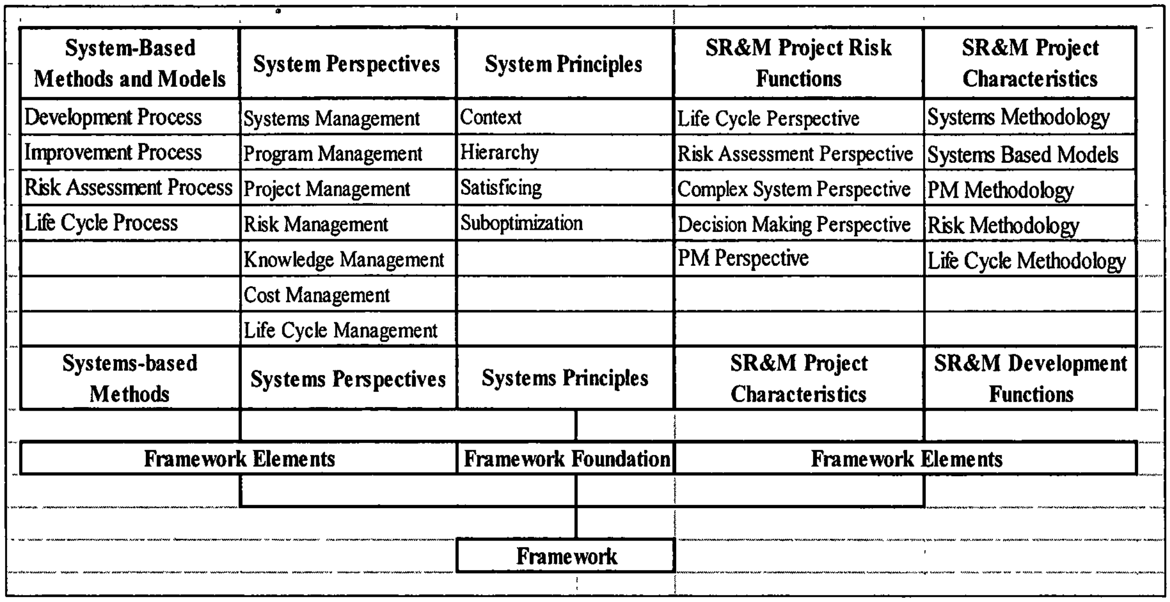
The question of what is the relevance of risk management to the problem must be addressed as well. The deferral of any inspection, repair, or maintenance on a ship's system, sub-system, or component requires a risk assessment as to its impact on the ship's mission capabilities. For any SR&M inspection, project or job to be deferred, reassessment of the affected system, subsystem, and/or component should in all probability be re-assessed as evidentiary of a potential increase in the risk of failure or reduced operational capability. Delays in timely scheduling for inspection, projects, or work items for a ship's system, subsystem, or component will logically increase the likelihood of future problems of a greater nature and consequence, and resultant increased repair costs.

The relevance of current practices and policies of the SR&M may be addressed as a "problem." The current practices for ships entering into either continuous or restricted availabilities is to have scheduled maintenance projects or jobs deferred for a number of reasons, be it funding, time, resources, conflict with higher priority repairs/maintenance work, or other engaged or disengaged reasons. Not all projects or jobs can be accomplished in accordance with established standards, whether it is due to the system, subsystem, or component design requirements or from industry custom and practices, facility availability, or time constraints. The Navy SR&M program includes many commands with varying engaged and disengaged objectives in determining what needs to be accomplished in a ship's repair and maintenance availability. The current organizational process in Figure 7 shows the lines of communication and responsibility for the ship repair and maintenance process, with the specific organizational responsibilities listed below:

- NAVSEA 00 provides technical authority guidelines and policies to be executed by the CRMC via Chief Engineers. (USFFC & TYCOM do not have technical authority)
- NAVSEA 05 provides the tech authority to the CRMC.
- CRMC provides tech guidance & chief engineers to NSSA RMC.
- NSSA RMC coordinates and schedules resources for ship availability using CSMP inputs and JFFM guidance.
- RMCs (NSSA) provide technical support to ships.
- NAVSEA 04 provides guidance & oversight to naval shipyards.
- NAVSEA 05 provides engineering policy & guidance to U S Navy and additional supporting service requirements to NAVSEA 21 and SURFMEPP.
- SEA 21 oversees & funds ship modernization work items via the class ICMP
- SEA 21 provides requirements to SURFMEPP
- SURFMEPP "brokers" expected ship life cycle work to ICMP
- USFFC via TYCOM schedule ship maintenance periods
- USFFC provides life cycle policy to SURFMEPP to monitor life cycle management & modernization requirements for developing ship work packages in accordance with the JFFM..
- USFFC & TYCOM (CNSL) reviews ship readiness data from Maintenance Figure of Merit (MFOM) to determine guidelines for prioritizing required work vice ship operational capability.
- TYCOM provides feedback to SURFMEPP for input to ICMP.
- TYCOM provides funds for SR&M work

- TYCOM defines the work package through their Port Engineer, who executes the availability.
- INSURV and all readiness inspections provide input to CSMP, which are rolled up by SURFMEPP to the ICMP.
- ICMP contains all technical requirements to review and evaluate the material condition of ships.
- The CSMP contains all ship maintenance work items that have been documented by ship's personnel.
- The CSMP is the repository of all maintenance conditions for each ship, and is the baseline for inspections, repairs and maintenance items/jobs/projects.
- Ship inspections (INSURV & Readiness Assessments) provide information and trends on needed repairs and maintenance submitted to the CSMP.
- The CSMP is reviewed during the planning board for maintenance with ship's force, TYCOM, ISIC, and RMC to help define the ship's availability work package.
- CNSL defines the ship's availability work package from the ICMP and CSMP.
- NSSA RMC coordinates and schedules the resources needed to accomplish all work items and jobs identified for the availability period.

The current policies are directed to complete all identified work items or jobs within the scheduled time period, budget constraints, compliance with established procedures and meeting quality operating specifications and standards. NASA and INCOSE practitioners believe systems engineering processes (analysis and design) was instrumental in their project successes. It may not be too much to suggest that applying project risk management and life-cycle assessment for a complex system would optimize a ship's repair and maintenance posture, resulting in an improved ship material readiness in the short term, and cost savings over the long term.

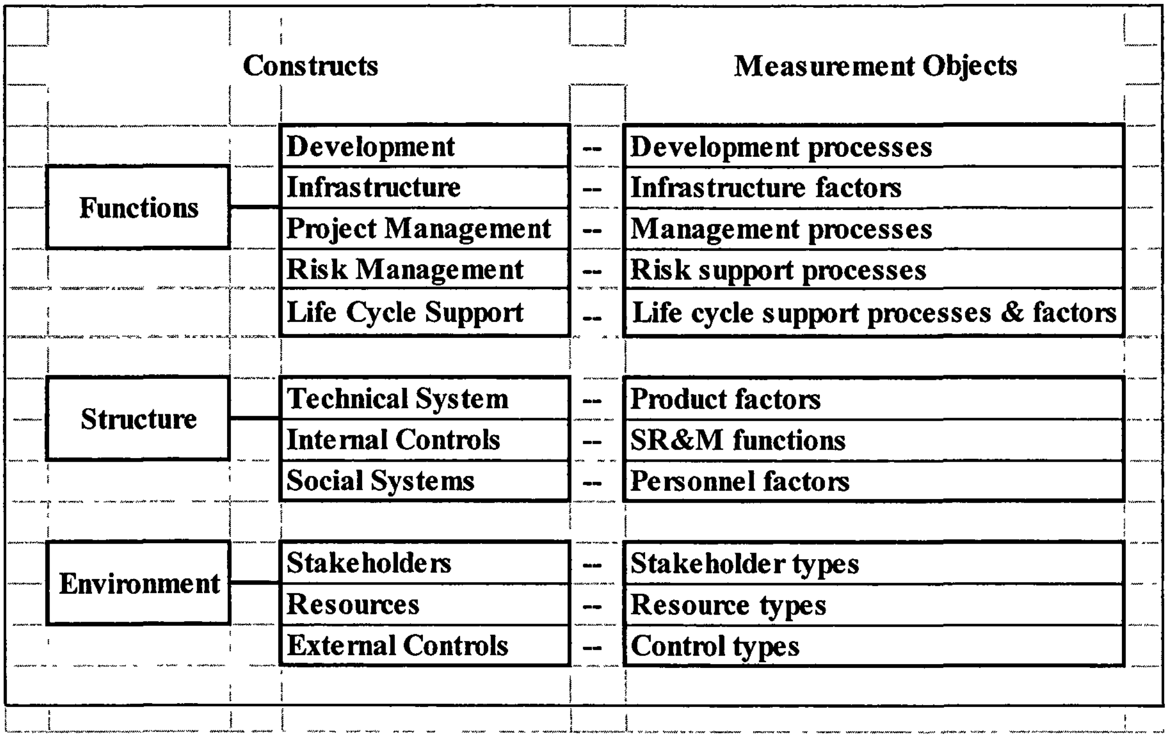


System-Based Methods and Models	System Perspectives	System Principles	SR&M Project Risk Functions	SR&M Project Characteristics
Development Process	Systems Management	Context	Life Cycle Perspective	Systems Methodology
Improvement Process	Program Management	Hierarchy	Risk Assessment Perspective	Systems Based Models
Risk Assessment Process	Project Management	Satisficing	Complex System Perspective	PM Methodology
Life Cycle Process	Risk Management	Suboptimization	Decision Making Perspective	Risk Methodology
	Knowledge Management		PM Perspective	Life Cycle Methodology
	Cost Management			
	Life Cycle Management			
Systems-based Methods	**Systems Perspectives**	**Systems Principles**	**SR&M Project Characteristics**	**SR&M Development Functions**

Figure 21: Theoretical Concepts Underlying the Framework

5.1.5 High Level of the Framework

Construction of the framework from the theoretical concepts was constrained by the framework features previously discussed in Chapter IV. The governing features were compiled from boundary conditions, the functional characteristics and framework influences and the pragmatic factors established for the framework, per Figure 20 and Figure 21. The governing features were compiled from boundary conditions and the functional characteristics relating to the theoretical concepts underlying the framework. The theoretical concepts were selected to reflect the pragmatic factors in establishing the underlying features of the proposed framework.



	Constructs		Measurement Objects
Functions	Development	--	Development processes
	Infrastructure	--	Infrastructure factors
	Project Management	--	Management processes
	Risk Management	--	Risk support processes
	Life Cycle Support	--	Life cycle support processes & factors
Structure	Technical System	--	Product factors
	Internal Controls	--	SR&M functions
	Social Systems	--	Personnel factors
Environment	Stakeholders	--	Stakeholder types
	Resources	--	Resource types
	External Controls	--	Control types

Figure 22: High Level Framework and Construct Elements

Construction of the framework from the theoretical concepts was constrained by the framework features established in Chapter IV. The governing features were a compilation of the boundaries and the utilitarian characteristics and factors established for the framework:

(1) Generalizable/Transportable to/for any complex system project.

(2) Analysis is based on systems principles.

(3) The framework validates its substantive meaning by comparison with empirical evidence and/or expert opinion.

(4) The framework must be easily understood by engineering professionals.

The shape and elements of the framework were a result of the application of the underlying theoretical concepts within the four governance factors. Figure 22 is a high level view of the constructs and measurement objects.

It should be noted that all underlying theoretical concepts have been transformed to the framework theory and construct elements. A construct is a concept; but additionally means that "...having been deliberately and consciously invented by the researcher from his own imagination, to represent something that does not exist as an isolated, observable dimension of behavior." (Nunnally & Bernstein, 1994) The eleven constructs in Figure 22 bridge the gap between theory and measurable empirical phenomena. Each construct was supported by objects having attributes which have criteria subject to measurement, that is to say, yielding a measure. A measure is defines as "...an observed score gathered through self-report, interview, observation, or some other means." (Edwards & Bagozzi, 2000) The measures were important because they linked the observable, real-world, empirical facts and the unobservable constructs in the theoretical framework.

The individual measures supporting the constructs were designed by the researcher to reflect or manifest the observable construct and to respond to variation in the construct. "The direct reflective model specifies the relationship between the construct and its measures, factor loading, and measurement error." (Edwards & Bagozzi, 2000) "The causal nature of the relationship between constructs and measures has been the focus of continuing debate, although the literature suggests an emerging consensus based on four conditions for causality." (Edwards & Bagozzi, 2000) The four conditions, per Edwards & Bagozzi are:

- Distinct entities: The construct and measure must be distinct.
- Association: The construct and measure must co-vary, where the researcher must rely on the use of co-variances among the multiple measures of the construct.
- Temporal Precedence: This addresses whether change in the construct precedes, accompanies, or follows the change in measure.
- Elimination of Rival Causal Explanations: "Ruling out rival causal explanations is a daunting task that cannot be reduced to universal prescriptions." (Edwards & Bagozzi, 2000)

The relationship between the reflexive measures and the constructs in the framework satisfy three of the four conditions for causal directivity. What was needed was a technique capable of measuring the constructs and measurement objects, hence "measurement instruments that are collections of items combined into a composite score, and intended to reveal levels of theoretical variables not readily observable by direct means, are often referred to as scales. We develop scales when we want to measure phenomena that we believe exist because of our theoretical understanding of the world, but that we cannot assess directly." (DeVellis, 2003)

5.1.6 Development of Scales for the Framework

The procedure to develop the scale is based on the theoretical hierarchy in Figure 19 that supports the framework:

- Framework: contains constructs
- Construct: contains measurement objects
- Measurement Object: contains attributes
- Attributes: contains criteria that can be measured

The framework included three construct elements: Functions, Structure, and Environment. Each construct of the framework was based on the theoretical concepts presented in Figure 22.

This ship repair and maintenance framework has the potential to affect the U. S. Navy ship repair and maintenance industry by changing the way SR&M projects, work items, and jobs are selected to increase ship readiness; enable ships to meet the 35-year service life; and to decrease total ship cost. This change of selecting ship inspections, repairs, and maintenance projects, work, or jobs will likely cause initial increase in SR&M funding to "catch up" with deferred projects/work/jobs. The selection process will be a project risk management with a life cycle assessment of ship systems, sub-systems, and components that could impact mission readiness. An example could be an inspection on hull and void integrity that could have long term impact over a ship's 35 year service life. This inspection, if deferred long enough or ignored, will cause a simple inspection and possible resurfacing of a tank, to a more expensive repair such as the replacement of deteriorated steel plate and structural members. For example, the hull plating and structural members in a void are designed to sustain extreme sea conditions and their failure will cause greater risk on adjacent ship plating and structural members, possibly affecting other ship systems.

Ships in commission today were originally designed and built for an anticipated service life of 30 years. The current view is that a ship's service life must be 35 years. This requires that the previous ship repair and maintenance schedules must adjust their scheduled inspections, repairs, and maintenance to allow for the increased risk potential to mission readiness and increased life cycle costs.

The proposed framework encompasses tasks usually performed by managers and engineering personnel of U. S. Fleet Forces Command (USFFC) and Naval Sea Systems Command (NAVSEA), including directors in each sub-section and shop, such as command, planning, logistics, operations, engineering, and associated sub-sections and contractors. The Navy repair and maintenance program will be broken into the following areas of interest:

- Stakeholders
- Project Risk Management Areas
- Life Cycle Area
- Project Risk Area
- Scheduling Area
- Technical System Area
- Resource Area
- Infrastructure Area
- External Control Area

Each area was delineated in relation to their organization, objectives, and metric of interest in the decision-making process for ship repair and maintenance availabilities.

The stakeholders are officers and managers in Department of Defense organizations and bureaus, and commercial companies providing expertise, facilities, workers, materials, components, equipment, and/or parts for the ship repair and maintenance industry. Their objectives may be either engaged or disengaged with their responsibilities and organizational purpose and function as well as with their influence and interest levels in a particular ship class or ship's repair and maintenance availability period. Each manager in each organization performs their function under the constraints of time, budgets, scope and cash flows, with the additional uncertainty in the availability of using or sharing physical resources. The metrics are based on degrees of decision successes.

Project managers are responsible for executing the project to produce the deliverable of a successful ship repair and maintenance availability period. The project risk manager assesses the degree of risk or uncertainty at each stage of the ship repair and maintenance process. The objective of a risk assessment is to calculate the levels of uncertainty and sources of risk, such as scheduling, cost, technology and organizational, political, policy and personnel changes. The goal is to ensure an optimally successful ship repair and maintenance availability period. The metric for projects are time, budget, compliance with procedural methods, and quality.

The ship service life is determined to be 35 years for a navy combatant ship. The need for life-cycle costing is crucial because any decisions made in earlier phases, such as deferring routine inspections or maintenance will inevitably impact future repairs and maintenance costs. The uncertainty of life-cycle costing is further complicated by the ship's mission, activities, and the stresses and utilization of shipboard equipment and systems. This process is made more difficult by advances and changes in technology and ship systems. There are two metrics used: (1) a ship's mission readiness; and (2) the total life-cycle cost. If a ship has less than average number of days as mission ready and the life-cycle costs exceed what was estimated, fleet command will look into the reasons and causes, and take appropriate action. Options may be early decommissioning so funding can be reallocated to other ships or new construction projects.

A ship's service life of 35 years requires periodic inspection, repair, and maintenance of ship hull, mechanical and electrical as well as combat systems. Project scheduling deals with the establishment of a timetable during which inspection, repair, and maintenance services are to be accomplished and facilities available for the conduct of the maintenance period. Fleet Force Command (FFC) operational scheduling integrates availability periods. Some work items take technological precedence over lesser critical items. Norfolk Ship Support Activity Regional Maintenance Center (NSSA RMC) assigns facilities with appropriate availability of dry-docks, heavy life machinery, ship materials, equipment, and parts, as well as any outside influences to timeline limitations.

The many systems on Navy ships are nearly identical within each ship class. The yard and pier facilities are well maintained and have trained and experienced personnel knowledgeable in the various ship systems. This provides an advantage for shipyards and commercial ship repair and maintenance organizations in that their workforce is familiar with repairing and maintaining shipboard systems and machinery. The bidding of contracts for ship repair and maintenance is highly competitive. Since governmental yards, facilities and personnel are limited in size and capability, the resource for having an experienced workforce of subcontractors to complete projects and/or jobs, while meeting the Navy's quality metric and procedural standards, is an extremely valuable asset.

Resource planning is the process wherein the project manager decides which resources to obtain, from which source, when to obtain them, how to use them, and when and how to release them. The resources expended on the Navy's ship repair and maintenance are very large in numbers. The project manager is responsible for meeting the projected budget expenditures as scheduled. Any deviation requires an analysis of what occurred and why. The metrics used are monetary for materials, parts, man-hours, procedural standards and quality, and/or equipment.

The infrastructure needed for ship repair and maintenance is concerned with governmental and commercial facilities and workers. From the department of defense perspective, all yards and pier facilities must be maintained, and trained and experienced personnel must be knowledgeable in shipyard systems and equipment must be available for use. The government shipyards and piers are maintained for obvious reasons. The commercial facilities must also keep their shipyards, repair depots, and facilities ready to use as they rely on obtaining ship repair and maintenance contracts from the U. S. Navy, U. S. Coast Guard, and the U. S. Army. Secondly, this author will note that the government facilities and yards are not capable of handling the requirements for maintaining all military ship needs. The metric used is budgetary allocations for governmental yards and facilities, and contracted agreements with commercial facilities and equipment.

The external control area is presumed to be organizations outside of the Secretary of Defense. The Department of Defense (DOD) receives funding from Congress, through the legislative process. The DOD provides informational testimony of annual budget needs to congressional committees, regarding necessary funding for expected and anticipated operational commitments worldwide and for fleet readiness needs. The metric used is budgetary constraint of limited funding of taxpayer dollars. Historically, Congress can restrict or deny budgetary items for shipbuilding as well as base closures as witnessed in the past.

5.2 SR&M Framework Considerations

The commands involved in the ship repair and maintenance process provide inspection, repair, and maintenance line items for each ship class, maintained in the Integrated Class maintenance Plan (ICMP). The purpose is to ensure that the ship class ICMP and the ship's Current Ship Maintenance Project (CSMP) contains all inspections, repair and maintenance work items/jobs with note of their periodicity of scheduling. The purpose of the Surface Maintenance Engineering Planning Program (SURFMEPP) Activity is to identify items and make the case for their inclusion in each ship's availability work package conference. The goal is to:

- Ensure that inspections and SR&M work items be done on or before required periodicity.
- Eliminate or drastically reduce the deferment of inspections and SR&M work items explicitly based on system, sub-system, or component life cycle assessment.
- Planning and Engineering for Repairs and Ship-Alterations.

The Navy has many commands with many engaged and disengaged objectives in determining a ship's repair and maintenance scheduled availabilities. The framework delineates the changes to the current ship repair and maintenance process structure as well as the command actions and responsibilities. The proposed change will affect the decision making responsibility for deferring a ship's work package. The Surface Maintenance Engineering Planning Program (SURFMEPP) Activity will have oversight authority to restrict the deferring of inspections, repair and/or maintenance work items, where their previous responsibility was to advise TYCOM and notify NAVSEA 05 of the decision. U.S. Fleet Forces Command (USFFC) will accept the recommended decision unless extreme operational requirements dictate otherwise.

Based on Figure 23, SURFMEPP will use project, risk-based, ship life-cycle criteria, performing the decision analysis to determine what SR&M items are to be accomplished during a scheduled availability. The proposed framework for SR&M process diagram keeps the same lines of communications except when making decisions about deferring ship inspections, repairs and maintenance items which are made via the SURFMEPP Activity, which falls under the purview of the Type Commander (TYCOM) who retains the ultimate authority and final word based on fleet operational commitments.

SURFMEPP's current function is in an advisory role in the decision making for choosing which inspections, repairs and maintenance work items are to be completed or deferred. Figure 23: Proposed detailed framework for SR&M process indicates an additional line of communication and authority between SURFMEPP and USFFC.

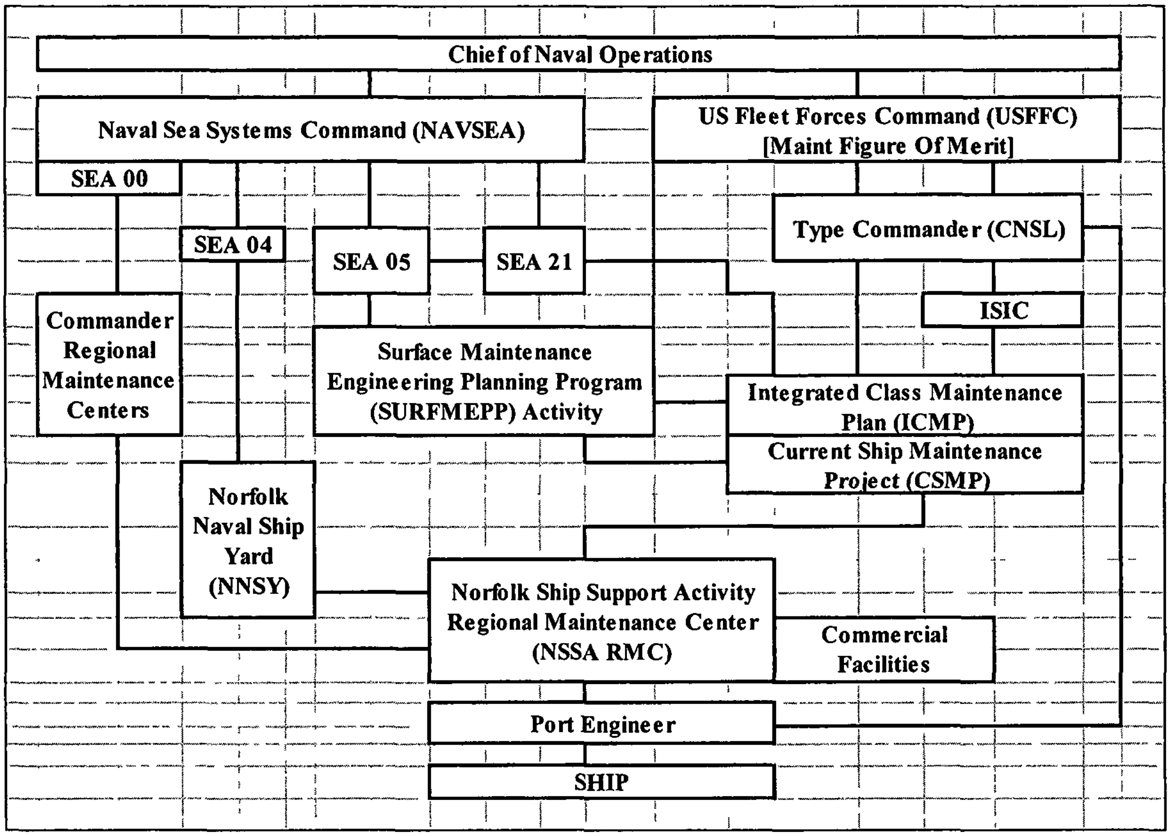


Figure 23: Proposed Detailed Framework for SR&M Process

The added linkage makes SURFMEPP a decision maker in deciding whether to defer ship inspections, repairs and maintenance work items beyond their recommended periodicity, and the impact it will have on the 35-year service life. The TYCOM will no longer have unilateral authority to decide which deferred work items are deemed non-critical based on short term estimates of risk.

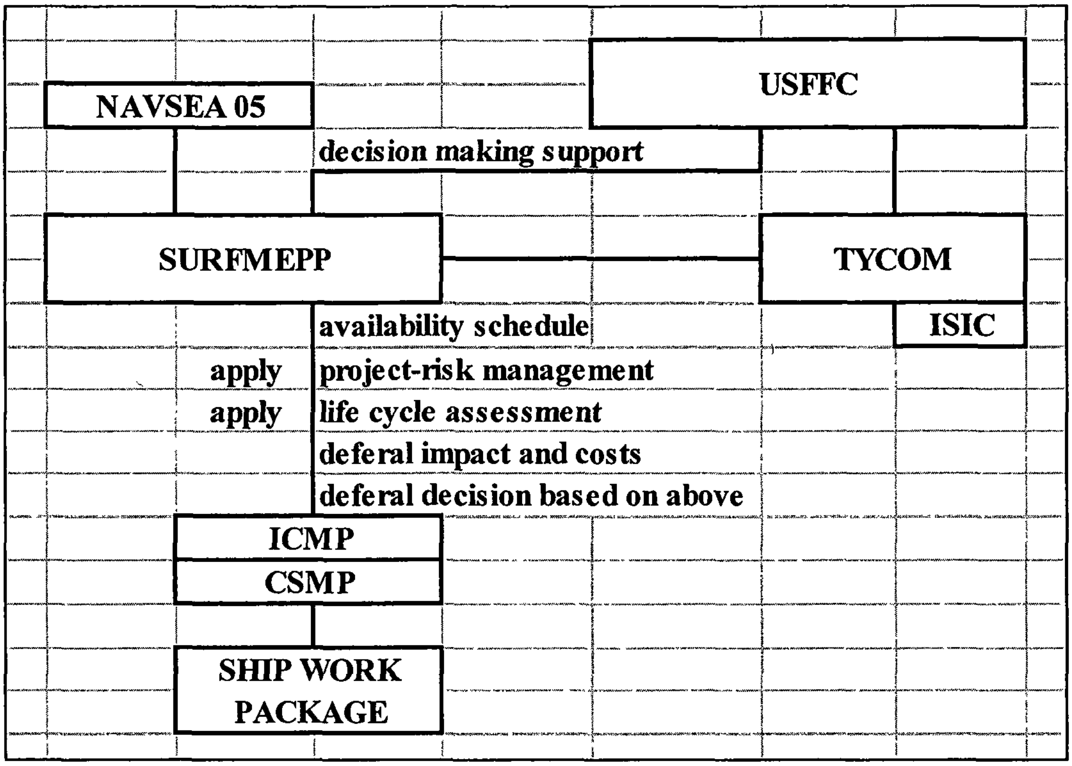


Figure 24: Proposed Deferral Decision Making Process.

SURFMEPP will have an increased role with TYCOM in making any deferral decision. SURFMEPP will base their decision solely on negative 'ship service life' risks for system, subsystem, or component failures, as well as future repair and maintenance costs.

The following questions will be individually addressed:

1. Who will mandate the inspection schedule?

The inspection schedule will be mandated by USFFC and used by the SURFMEPP Activity. A risk management assessment should reinforce the periodicity for inspections, repairs, and maintenance that impact the ship's 35-year service life from the perspective of the ship operating at full capability.

2. Who will have oversight in determining if and when inspections, repairs, and maintenance work items will be scheduled for the current or next availability?

The inspection schedule, mandated by USFFC, will be controlled by the Surface Maintenance Engineering Planning Program (SURFMEPP) Activity from the depot repair and maintenance level. The focus should be the risks inherent to a single, cascading, or complete ship sub-system or system failure affecting the ship's readiness posture

3. What information is needed to determine if the ship's service life is jeopardized and by whom?

The risk evaluation will include the future impact on the ship's life-cycle cost, and the hull, mechanical, and electrical (HM&E) material perspective of the uncertainty in the ship maintaining a maximum readiness posture for a specific sub-system or system and its impact on other ship systems.

4. Are the stakeholders aware of the system risks of deferring inspections, repairs, and maintenance items or jobs?

The stakeholders may have other disengaged objectives outside the purview of a ship's repair and maintenance availability.

5. How may commands weigh the tradeoff between ship schedule and service life?

The decision to schedule and perform or not to perform any inspection, repair, and/or maintenance action should be made at the lowest level possible, and the framework indicates that the Surface Maintenance Engineering Planning Program (SURFMEPP) Activity is fully cognizant and capable of making "*THE*" decision.

6. How can project risk management provide insight into the risks involved in ship repair and maintenance and provide an optimal balance of ship readiness over its 35 year service life.

The Surface Maintenance Engineering Planning Program (SURFMEPP) Activity, with input from all commands in the navy hierarchy via the ICMP, and the ship's CSMP as to what inspections, repair and maintenance projects and jobs will be scheduled for accomplishment at an upcoming scheduled availability period.

7. What alternatives/decisions need to be evaluated/made by whom and when?

The Integrated Class Maintenance Plan (ICMP) lists all of the projects and jobs for each class of ships, and they are included in each ship's Consolidated Ships Maintenance Plan (CSMP). The projects and jobs are discussed at a Ship Availability Meeting, consisting of the various organizational (stakeholders) representatives:

- Ship: Commanding Officer, Chief Engineer, & Overhaul Coordinator
- Type Commander Representative
- NSSA RMC: Project Manager, Waterfront Coordinator
- Surface Maintenance Engineering Planning Program (SURFMEPP) Activity {the decision maker}
- Technical representatives (as needed)
- Facility Managers (government & commercial)

- Contractor(s) Project Managers and Specialists
- Other interested parties (as necessary)

The details of the upcoming availability are discussed concerning what can be accomplished during the timeframe allotted. Projects and job alternatives are discussed, evaluated, and decisions are made based on facts and risks, materials and parts availability, equipment logistics, staging pier side, and available shore equipment, dry dock facilities and crane services, and supporting equipment and material handling vehicles.

8. What are the measurable outcomes if this framework is implemented?

The outcomes may not be realized for several years into the ship's service life as there will be an expenditure spike to enable the ship to catch up on deferred inspections and repairs or maintenance previously not accomplished, requiring worsened material conditions to be remedied at higher costs than if done years earlier. Secondly, the added or catch up work may impinge on current work items being accomplished within the scheduled availability period. This may require longer scheduled availabilities than previously scheduled. One potential outcome may be a reduction of total ship-life cost. The ship cost outcome may not be realized for several years after the framework is used in a single ship pilot study, as there will be increased expenditures in the beginning to "catch up" with deferred inspections, repairs, and maintenance projects and jobs. The vessel life cycle cost should prove to be a good estimate of future repair and maintenance costs, based on future technological developments and advances, and mission changes requiring added ship capabilities.

5.3 Validation of the Framework

The framework was validated by Subject Matter Experts (SME) who are senior program (uniformed and civilian) managers working in the Navy's ship inspection, repair, and maintenance program from different commands. The results of these SMEs are documented in Appendix C. Their replies to the Questionnaire are noted with the analysis and synthesis of their validation comments on the proposed framework process are based on Appendix C, Tables 8, 9, 10, 11, and 12.

Key findings from the industry assessment are discussed and summarized in Table 12: Survey Response Analysis (Appendix C). A question by question analysis of each of the subject matter expert's comments is tabulated in Table 12 and a line-by-line summary follows:

- Question 1: The Subject Matter Experts indicated an overall positive expectation of 25% that the short term impact would be acceptable, and have a 19% negative impact on resource allocation.
- Question 2: The Subject Matter Experts indicated an overall positive expectation of 36% with only a 3% negative impact on long term resource allocation.
- Question 3: The Subject Matter Experts indicated an overall positive expectation of 43% with only a 9% negative impact on the scheduling of resources.

- Question 4: The Subject Matter Experts indicated an overall positive expectation of 50% with a zero negative impact on the scheduling of ship deployments.
- Question 5: The Subject Matter Experts indicated an overall positive expectation of 31% with a 3% negative impact on the scheduling of the Total Ship System Readiness Assessment program.
- Question 6: The Subject Matter Experts indicated an overall positive expectation of 30% with a zero percent negative impact on the Reliability Centered Maintenance program.
- Question 7: The Subject Matter Experts indicated an overall positive expectation of 29% with a zero percentage negative impact on a ship reaching its 35-year service life.
- Question 8: The Subject Matter Experts indicated an overall positive expectation of 50% with a zero percent negative impact that the decision making process for a ship's availability work package would improve.
- Question 9: The Subject Matter Experts indicated an overall positive expectation of 9% with an 18% negative impact for concerns that the framework would be implemented.
- The aggregate analysis of the Subject Matter Experts indicated an overall positive expectation of 34% with a 6% negative impact on the proposed framework and its benefit in improving the Navy's ship repair and maintenance program.

To summarize, the proposed framework would improve the decision making process and minimize the deference of work based on factors outside of the ship's "best" long-term interest vice the current practice. The proposed project-risk and life cycle assessment framework would provide a more visible influence in choosing scheduled inspections within predetermined periodicity. The project-risk and life-cycle assessment framework affects the decision-making process in choosing the time table for which the work is to be accomplished based on current risk analysis measures within the navy command structure. The analysis of the Navy's ship repair and maintenance process provided a unique and challenging view of the engineering management of this very large and complex system of systems.

5.4 Summary

This chapter explicates the results of the research. The industry subject matter experts provided valuable insights into the complex system of multiple organizations involved in the decision-making process of selecting repair and maintenance items that are to be accomplished during a ship's availability. The two major elements are the Framework Construction and the Framework Validation. The framework was constructed using the literature review and deductively ascertained how the Navy SR&M program functions and how a project risk management and life-cycle assessment systems engineering approach may improve program results. The resulting framework satisfies all of the theoretical elements by deduction. The framework was validated by specific questions posed to senior managers, both uniformed and civilian Navy Subject Matter Experts, working in different commands within the Navy's SR&M program. The industry subject matter experts (practitioners) provided valuable insights into the information needed, and about the multiple organizations that are involved in the decision- making process of selecting which inspections, repair and maintenance items are to be accomplished in a ship's availability.

CHAPTER 6

DISCUSSION OF RESULTS

This chapter provides a discussion of the conclusions drawn from the research outcomes. The first discussion centers on the research as measured by the objectives of the study and research questions. The second discussion discusses the framework areas and its ability to improve the performance of a complex system, such as the Navy's ship repair and maintenance program.

6.1 Research Objectives and Question

This section discusses the conclusions drawn from the research. The purpose of this research was to develop a systems-based, project-risk and life-cycle based framework to improve a complex system. The research purpose was supported by the research objective and questions. The presentation of the research conclusions will begin by reviewing the research purpose and question identified in chapter 1.

The research had a single objective, that being to develop a literature based, case study framework applying project risk management and life-cycle assessment to ship repair and maintenance scheduling. The second objective is to create a general and transportable framework that is capable of working with other complex systems. Based on these objectives, the research focused on answering the research question:

How can systems engineering theory apply to the analysis of project-risk and life- cycle management performance for ship repair and maintenance?

The central issue to be determined is whether the purpose of the research was met and the research questions answered. The answer is that the research fulfilled these requirements and is supported by the achievement of the following research outcomes:

- Employment of a qualitative case study method to develop a theoretical framework using an engineering research methodology for complex systems.
- Applying systems theory to view a complex systems engineering construct such as the Navy's SR&M program.
- The development of a framework to be used to improve the decision-making process in the Navy's SR&M program.

It can be stated that the purpose of the research, when considered against the outcome, has met the objectives and answered the research questions posed.

6.2 Methods of Engineering Research

The use of a case study method to develop a theoretical framework as an engineering research method for a complex system may not be a groundbreaking technique, but applying project-risk management with life-cycle assessment exclusively is not, nor has it ever been done.

6.3 Systems Engineering and Project-Risk Management

The research has developed an alternative to the current management process for the Navy's SR&M program. The proposed SR&M Framework a new systemic view that uses the current structure with a new dimensional function and paradigm. This new holistic view has the potential for improving ship inspection, repair, and maintenance item/project/job selection process. A paradigm will require a shift from the current SR&M program to the proposed SR&M process.

- The research has generated a framework that provides a new and logical view of the SR&M process through the lens of a systems engineering application of project-risk management and life-cycle assessment in decision making. The systems lens shows that the levels of analysis: function, structure, and environment.
- The developed framework utilized principles from project-risk management that provided a view of the SR&M process in the risk assessment of ship systems, sub-systems, and component risks and their interconnected risks for operational performance, periodic inspections, work compatibility/scheduling, availability of shore-based resources and manpower limitations during an availability period.
- The developed framework, which utilized life-cycle principles borrowed from INCOSE systems engineering principles, provided a distinct view of the ship systems, sub-systems, component life-cycle risks and interconnected risks for a ship mission performance as in relation to the SR&M process of periodic inspections, repairs, and maintenance within an available period.
- The developed framework specifies the decision-making authority for selecting what ship's inspections, repairs, and maintenance are to be accomplished in the availability work package to be made at the lowest command level as possible, that being the Surface Maintenance Engineering Planning Program (SURFMEPP) Activity.

The new paradigm fulfills the SR&M Framework as an element of a paradigm shift in the Navy's command structure, and transferrable to other complex organizational systems.

6.4 Framework Development

Systems theory and the hierarchy of laws, principles, theorems, hypotheses, and axioms are the basis from which the source of the idea for a systems-based framework to improve the Navy's SR&M program and process. The body of knowledge provided in the elements shaped this viewpoint. The resulting framework was developed in part from the real world of the Navy's ship repair and maintenance program. The method of selecting the SR&M inspections, projects, and jobs may not be revisionary, but the precedence used to select the more "worthy" projects to be accomplished is the focus. For example assessing the potential risk of future failure or degraded operations and how a specific component, sub-system, and /or system will impact the ship as a whole.

The framework incorporated the traditional functional analysis of engineering management, systems-based elements, which are structure and environment. The structure analyzed the hierarchical nature of the Department of Defense (DOD) and U. S. Navy command and management structure. The environmental aspect identified stakeholders and external controls and resources within the U. S. government political system.

6.5 Framework Measures

In Chapter 5, the completed framework was presented as a skeletal frame, populated with empirical evidence from governmental directives, policies, instructions, notices, and practices. The goal of this framework is to improve the current SR&M program and procedure for the decision making process of determining availability, inspections, projects, and job selections based on project-risk management and life-cycle assessment. There will be no quantitative measurement, nor other metric available as the ship data will be forthcoming in future years as budgets and ship mission readiness statistics.

However, the systems engineering, project-risk management with life-cycle assessment systems-based framework was validated using subject matter experts from senior uniformed and civilian management positions within the Navy's SR&M program. The anticipated commands affected by the proposed framework will be: management, resources, stakeholders, and manpower.

The management impact will be changed and will reflect the adage that the best decisions are made at the lowest levels of control. The decision making authority of which inspections, projects, and jobs are to be accomplished for a ship's availability will reside with SURFMEPP Activity, and not as dictated from Fleet Forces Command or Naval Sea Systems Command. Senior managers must rely on the SURFMEPP to make decisions based on project-risk management and life-cycle assessment and to ensure that the ship's service life takes precedence over other considerations.

All resources allocated for ship budgets will see initial increases in expenditures to accomplish overdue ship inspections, deferred repairs, maintenance projects and jobs. The initial outlay of funds should be recouped in later years due to the timely inspection, repair, and cyclic activities for maintenance and the reduction of emergency ship repairs and maintenance impacting ship schedules overseas. The identified tradeoffs will be among total vessel life cost, periodical costs, and total portfolio cost for entire ship classes.

The repair and maintenance facilities will also see an increased utilization schedule, which may impact on dry dock, pier, and lifting equipment and machinery. The increased use and utilization of repair and maintenance facilities will logically require initially greater expenditures of budgeted funding.

All stakeholders in the SR&M process would have to agree to the proposed framework, and accept that the decision-making authority resides with SURFMEPP, in terms of inspections, repairs, and maintenance jobs that are to be accomplished during a scheduled availability. The decision-making authority currently resides with Fleet Forces Command, and due to the rigid command structure, it is extremely doubtful that it will be delegated since "with responsibility comes authority."

All government and commercial organizations will have to focus on the repair facilities and the increased utilization thereof, which will necessitate an increased need of skilled personnel to operate facilities and perform the necessary tasks of operating dry docks, pier services, and heavy lift equipment and machinery. The increased utilization of repair and maintenance facilities will require an increased expenditure of resources for expansion and improvement.

6.6 Case Analysis Triangulation

The case study triangulation was accomplished by a questionnaire sent to subject matter experts which is documented in Appendix C. Based on three factors, the experts were able to deduce whether the framework is practicable and/or has the potential to improve the Navy's SR&M process and its physical and fiscal outcomes. The three factors are: the proposed framework, changes in the decision-making authority and the decision-making methodology.

6.6.1 Industry Findings

Key findings from the industry assessment are contained and summarized in Tables 8, 9, 10, 11, and 12. These tables were utilized to display the data from the survey and interviews of the four subject matter experts and industry practitioners are explained below.

Table 8: Industry Respondent Summary Questions (Appendix C) was created to combine each subject matter expert's raw data analysis of the proposed framework via the question. This method allows each respondent's expert opinion to be visible alongside each other and permitted a total view of data collected. This table permitted respondent data to be compared and analyzed as a group on a question by question basis. Weber (1985) indicated the need for "text classification" to categorize and code the text by content analysis.

Table 9: Question Analysis Cards (Appendix C) offered a better analysis technique offering reliability, as mentioned as pertinent to content analysis, offering "stability, reproducibility, and accuracy (Krippendorff, 1980, p. 130 – 154)." Weber (1985, p. 16) and was created from raw data presented in Table 9: Industry Respondent Summary Questions. This was a necessary coalescence towards the triangulation of data and validating the framework. Each respondent's reply to each question was categorically analyzed using a text analysis of narratives using the *most frequent words* and *phrase*

prominence technique. Lastly, this metric provided only a general acceptance, neutral, or negative response to the proposed framework, and did not provide conclusive evidence by the question.

Table 10: Industry Assessment Analysis by Question (Appendix C) was created from raw data presented in Table 9: Industry Respondent Summary Questions. Recorded comments and phrases were noted, analyzed, and grouped by their relevance and similarity and listed individually, and further identified as made by each respondent and or other respondent(s). Respondents are noted as 1, 2, 3, and 4 only. The creation of this table permitted grouping of comments by respondents creating agreement or not of each individual question relevant to the proposed framework on the current Navy SR&M program structure.

Table 11: Survey Response Analysis by Question was created to analyze respondent phrases into information elements from the raw data as presented in Table 10. Each of the respondent phrases were analyzed by question, with comments being positive, neutral, or negative in relation to the question and proposed framework. The total comments from each question were combined to determine whether their responses were positive, neutral, or negative, providing a percentage of agreement, neutral, or disagreement with each proposed framework based question.

Overall the subject matter experts determined that the proposed framework would be beneficial to the current repair and maintenance process for naval ships and would improve their chances of reaching their 35-year service life. Survey results by question as follows:

- ✓ *Question 1: What will be the short term impact on the ship availability process?* Industry SMEs indicated: 25% positive, 56% neutral, and 19% negative impact on success.

- ✓ *Question 2: What will be the long term impact on the ship availability process?* Industry SMEs indicated: 36% positive, 61% neutral, and 3% negative impact on success.

- ✓ *Question 3: What will be the scheduling impact on facilities/workforce for availabilities?* Industry SMEs indicated: 43% positive, 48% neutral, and 9% negative impact on success.

- ✓ *Question 4: What will be the scheduling impact on ship deployments?* Industry SMEs indicated: 50% positive, 50% neutral, and 0% negative impact on success.

- ✓ *Question 5: What will be the scheduling impact on the Total Ship System Readiness Assessment program?* Industry SMEs indicated: 31% positive, 66% neutral, and 3% negative impact on success.

- ✓ *Question 6: How will the new framework affect the Reliability-Centered Maintenance program?* Industry SMEs indicated: 30% positive, 70% neutral, and 0% negative impact on success.

- ✓ *Question 7: Will the proposed framework benefit a ship reaching its 35-year service life?* Industry SMEs indicated: 29% positive, 71% neutral, and 0% negative impact on success.

- ✓ *Question 8: Will the proposed framework contribute to better decision making in determining which repairs, maintenance, and inspections are to be accomplished during a scheduled availability?* Industry SMEs indicated: 50% positive, 50% neutral, and 0% negative impact on success.

- ✓ *Question 9: What concerns do you foresee in the Navy implementing the proposed framework?* Industry SMEs indicated: 9% positive, 73% neutral, and 18% negative impact on success.

Table 12: Survey Response Analysis (Appendix C) shows the aggregate percentages of the validity of the proposed framework. Overall responses are 34% positive, 61% neutral, and 6% negative for the proposed framework impacting the ship repair and maintenance process. Of note are the few negative responses for questions 2 through 8, with question 1 and 9 having the largest negative value at 19% and 18% respectively. Question 1 asks the short term impact on using a pure life cycle methodology to select repair and maintenance items, which would require the completion of the current backlog of deferred work. Question 9 posed implementation concerns, which places SURFMEPP as the deciding command over operational commands such as U. S. Fleet Forces Command and Commander Naval Surface Forces Atlantic. No commander wants to lose influence or power in their areas of responsibility.

6.6.2 Researchers View

Part of this study required the participants (SMEs) to provide feedback relative to their perceptions of the proposed framework from the perspective of their senior level positions and command primacies. Responses were identified as explanations of agreement or disagreement. The interpretation of SME responses were collected into distinct pattern codes associated with each of the nine open ended questions. See Table

10. The below summary indicates positive and negative responses associated with each SME response.

Question 1 received 9 positive responses and 5 negative responses. Negatives can be summarized as increases to SR&M budgets.

Question 2 received 12 positive responses and 2 negative responses. Negatives related the need for increased maintenance periods to "catch up" on deferred R&M work, requiring increases in workers man-hours.

Question 3 received 17 positive responses and 6 negative responses. Negatives related to increases in depot level work and increases in private sector work.

Question 4 received 14 positive responses and zero negative responses. Ship schedules will remain inviolate of any changes of repair and maintenance processes or procedures.

Question 5 received 11 positive responses and 1 negative response relating to the impact on short term availability of manpower concerns.

Question 6 received 6 positive responses and zero negative responses. The proposed framework was considered to compliment and support the Reliability-Centered Program.

Question 7 received 7 positive responses and zero negative responses. The proposed framework would support a ship in reaching its 35-year service life.

Question 8 received 16 positive responses and zero negative responses. The proposed framework would contribute to better decision making in deferring needed SR&M projects and work.

Question 9 received 3 positive responses and 9 negative responses. Negative responses indicated reasons why the proposed framework will not be implemented. Funding for SR&M projects are inhibited by the decision maker with other objectives, insufficient funding, lack of tech warranted engineers, and changes in leadership and fleet goals, vision of the maintenance needs, restricted funding, budgetary processes, and changing political winds. The survey and follow up interviews resulted in favorable results that the proposed framework would have a positive impact on ships reaching their 35-year service life fully capable to perform their mission.

The responses from the SMEs tabulated by question and focused on the SR&M case study. Applying their responses of agreement (positive) or disagreement (negative) from each of the nine open ended questions was pursued with vigor. This qualitative sampling technique followed general sampling strategies recommended by Miles & Huberman (1994). The prime goal was to consistently reveal their perceptions of the proposed framework for SR&M from a complex systems perspective. To provide a balance between perception and reality the case study analysis was limited to the Navy's SR&M program.

Today, the organizational structure is generally the same with a few changes, such as the disestablishment of the POT&I group and recently the absorption of the CLASSRON organization into the TYCOM. NSSA RMC has been reorganized and is now falling under Norfolk Naval Shipyard. One new organization, SURFMEPP has been in existence for a little over one year and is in the process of hiring more engineers.

It is this author's opinion, based on SME validation, that SURFMEPP has the command linkages and the expertise to identify and force the issue to have all SR&M

periodicity requirements met, thus giving ships the best chance to reach their 35-year service life.

6.7 Industry Assessment Summary Findings

Four subject matter experts from different organizations within the Navy's ship repair and maintenance command structure were used in the expert-opinion elicitation process. In assembling and analyzing survey replies and the follow up interviews, the following points summarize the proposed project-risk management and life-cycle framework for complex systems, such as the ship repair and maintenance projects.

The industry subject matter experts and practitioners provided valuable insights into understanding the multiple organizations that are involved in the decision making process of determining the needed inspections, repair and maintenance items are to be accomplished in a ship's availability. The analysis of the Navy's ship repair and maintenance process provided a unique and challenging view of the engineering management of this large complex system of systems.

The choice of implementing the proposed framework is a separate issue, with the SMEs indicating that the chance of its acceptance is low for many reasons, not the least of which would be to relegate the authority in the decision making process to a lower echelon command. Two questions require consideration with the question under study:

The proposed project-risk and life cycle assessment framework would provide a more visible influence in choosing scheduled inspections within pre-determined periodicity.

The proposed project-risk and life-cycle assessment framework would affect the decision-making process in choosing which inspections are to be performed within recommended periodicity.

The basic proposal to use a project-risk management and life cycle assessment approach to manage ship repair and maintenance periodicity is sound, if based on the following recommendations:

- Changing the command structure of SURFMEPP addressing ships expected service life issues and a greater say in deferring or not deferring SR&M work items, especially for hull, mechanical, and electrical systems.
- Long-term ship availability will be improved due to well defined roll of SURFMEPP in the proposed framework. See Figure 27.
- The impact of the proposed framework will generate better efficiencies in the scheduling of the increased work and will possibly impact ship operational cycles.
- Due to the initiation of the proposed framework, in the short term, both public and private sector facilities and manpower will experience increases in the scope of work, and increase funding requirements. This would cause a negative short- term impact on resources and facilities.
- The proposed framework will not impact ship deployment schedules as these are, generally, inviolable from USFFC.
- The Total Ship Readiness Assessment (TSSRA) program will be positively impacted by the proposed framework in the long term by reducing ship system, equipment, and component downtimes and will improve the condition-based maintenance process.

- The proposed framework will compliment the Reliability Centered Maintenance (RCM) program.
- The proposed framework should allow a ship to meet its 35-year service life, if budgetary resources are let for the execution of technically required maintenance.
- The proposed framework will assist the "honest broker" to balance the risk and requirements aspect in making better decisions for scheduling ship inspections to determine needed repairs and maintenance. Question 9 responses indicated a negative chance of acceptance by higher commands.

6.8 Summary

The chapter has presented the results of the research and how it has fulfilled the objectives of the study and answered the questions. This dissertation has examined the roles of risk management and system life cycle in improving SR&M. In particular, barriers to optimized SR&M were identified, and a model has been proposed.

The framework brings together strengths from Risk Management, Systems Engineering, Engineering Management, Project Management, Risk Management, Life Cycle Management, and current practice in Ship Repair & Maintenance. Notable properties of this framework is the identification of a new decision node, the required information, and the sub systems that will be affected, such are management, resources, stakeholders, and manpower. The framework has been validated by a peer review by external audiences, and by a focus group of subject matter experts in SR&M.

CHAPTER 7

CONCLUSION

Chapter 6 presented a discussion of the results of the application of the framework for project risk management with life-cycle assessment for ship repair and maintenance to the case study. This chapter presents the limitations of the study, the implications of the results, and makes recommendations for areas in which further research may be directed.

7.1 Research Framework and Definition

This study uses a conceptual framework approach to NAVSEA vessels undergoing construction, repair, and/or maintenance. Figure 13 Research Design and Study previously indicated the study design for the completion of the research. Questions for surveys and interviews have been designed to answer posed questions and to validate the proposed framework.

The boundaries between the phenomenon and context for a life-cycle approach for ships or classes of ships are not clearly evident. Addressing the reality of shrinking budgets for shipbuilding, repair, and maintenance provides a distinctive situation in which there may be more variables of interest than usable data points. To this end, one must rely on multiple data sources of evidence. To provide a beneficial model, data collection and analysis is crucial. The data will need to converge in a triangulating fashion for corroboration for a viable and provable result to build a life-cycle model.

The inquiries investigate contemporary phenomenon with in real-life context. See Figure 25: Best Practices Steps for a Methodical Study Plan Process.

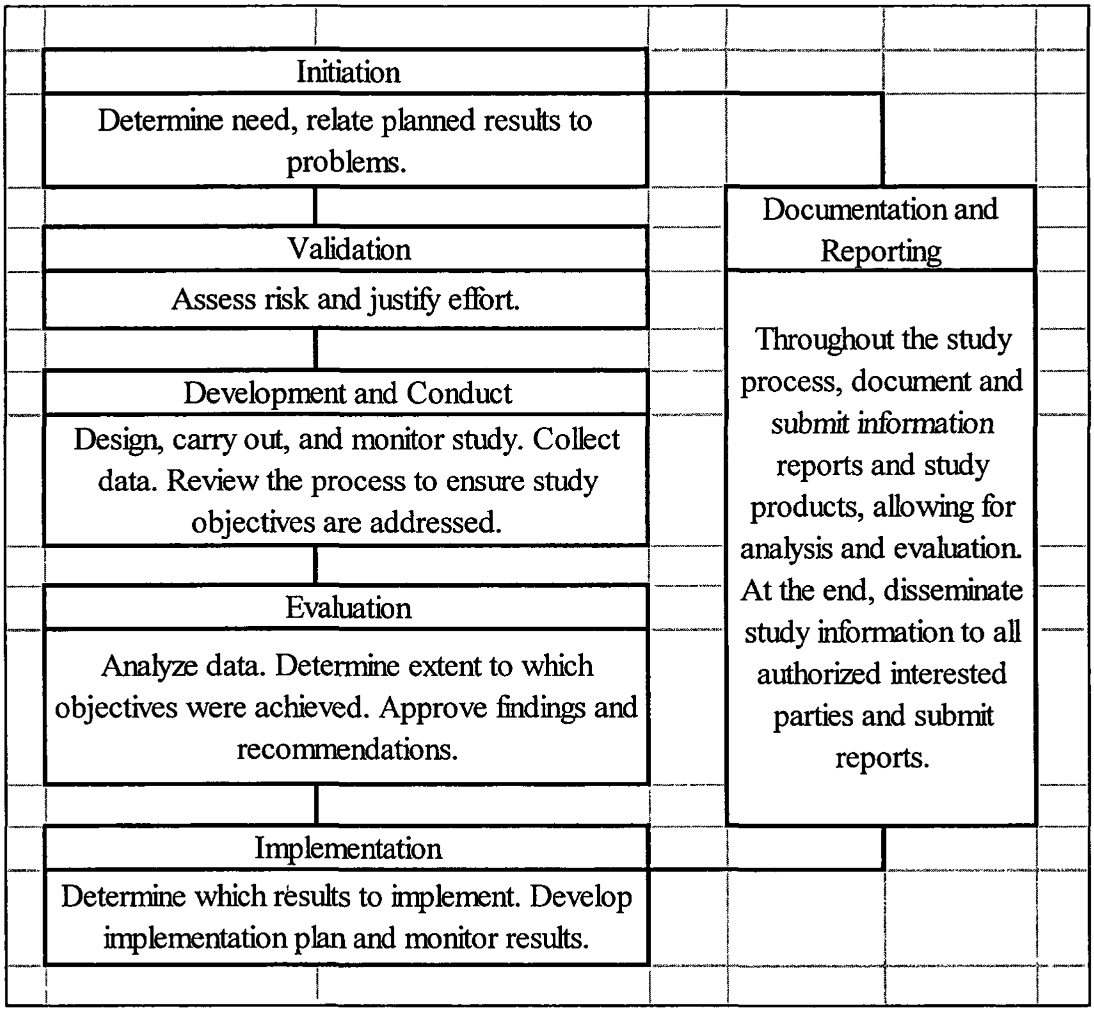


Figure 25: Best Practices Steps for Methodical Study Plan Process
Reproduced from GAO-06-84 Report, November 2005, *Military Readiness Navy's Fleet Response Plan.*

The framework includes the management of all individual vessel project risks as studied from the perspective of the vessel's entire life-cycle . The following assumptions will be adjudicated: past project performance may not be indicative of a problem-free environment; risk management is an integral component of project management; and reducing costs and duration of ship inspection, repair, and maintenance. Applied perspectives include: (a) a description of challenges to managing risks in ship projects and/or jobs; (b) the causes of these challenges; and (c) possible solutions.

7.2 Limitations of the Study

Before discussing the implications for the research, it is appropriate to mention its limitations. Three limitations are now discussed.

7.2.1 Limitation: Information Sources

The case study research included a questionnaire that relied upon the memories of professionals that reported on ship inspection, repair, and maintenance projects that had been completed, deferred, or canceled some time previously. This factor raises the prospect that there may be some error in the data, especially when the questionnaire answer was not supported by empirical evidence from the literature. Two factors were used to mitigate the possibility of error. The first factor ensured that more than one respondent was used in the case study. The second factor required the researcher to use formal logic in determining how the data was used to rate the project risk and life cycle application against the current measurement criteria. Figure 26: The Decision Tree below contains the logic used in comparing empirical data collected from the literature to the questionnaire answers and interview. The decision tree was used to evaluate empirical data using the proposed framework.

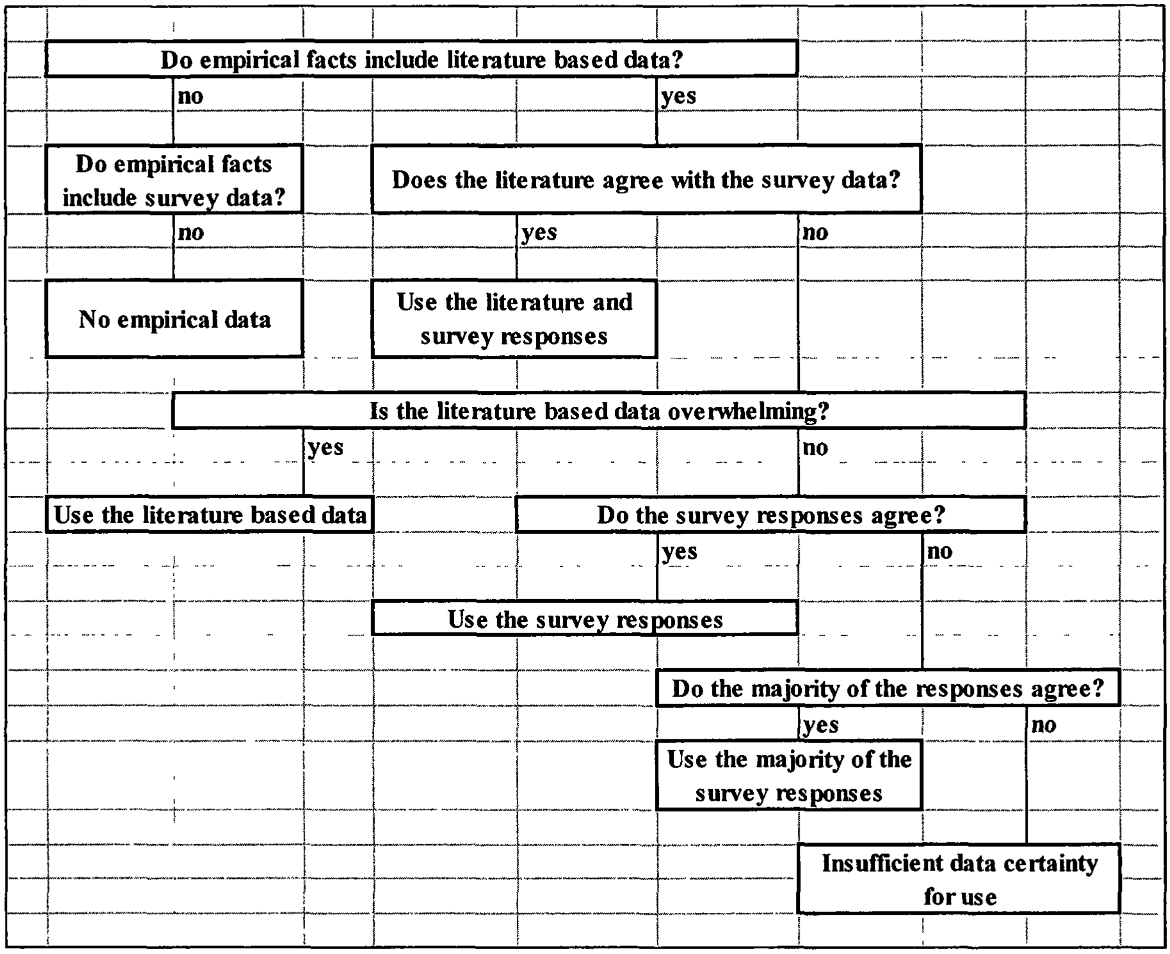


Figure 26: The Decision Tree

7.2.2 Limitation: Development and Measurement

The scales developed for the framework analysis were ordinal scales. There was no need to calibrate the scales against empirical evidence. The extension of this research may require future calibration and consideration if the framework is adopted for a wider study purview. The factors of political involvement were neglected in this research, and therefore were not measured.

7.2.3 Limitation: Project Risk Management Domain

In order to fully describe the large field of ship inspection, repair and maintenance projects and jobs, the framework criteria included all classes of ships and all types of ship inspections and repairs and maintenance projects and jobs equally. The following criteria were used to create the framework:

- The measure of the probability and severity of any adverse effects to a ship were excluded as part of this dissertation regardless of any impact on another component, sub-system, or system.
- The degree of risk or uncertainty was excluded as a part of this dissertation and not evaluated.
- The weighted criteria between or among inspections, projects, and/or jobs were excluded as a part of this dissertation, regardless of their duration, complexity, and/or cost.
- The risk assessments were neglected as a part of this dissertation, whether based on the individual assessments of an inspection conducted and a repair or maintenance project/job being scheduled for completion, based on a specific scheduling timetable or deferring of the activity in the next availability with a greater risk of failure or casualty to the ship's systems, sub-systems, or components, and mission impairment.
- The identification of the causes of pending failures, such as hardware, software, or human failure were excluded, however the use of failure due to organizational procedures, policies, customs, and practices were used as the basis for creating the framework.

- No risk assessment questions were used, such as: What can go wrong? What is the likelihood that it would go wrong? What are the consequences?
- No risk management questions were used, such as: What can be done, and what options are available? What are the associated tradeoffs in terms of all costs, benefits, and risks? What are the impacts of current management decisions on future options?

7.2.4 Limitations: The Researcher

This author is a retired naval officer, who has spent 10 years at sea in various positions of authority overseeing ship operations, inspections, repair and maintenance issues and system problems. Additionally the author was operations coordinator for a steam ship company transporting break bulk cargo as well as containers across the globe. Serving in positions from seaman to commissioned officer, as Operations Officer (Afloat), Overhaul Coordinator, and two tours as Executive Officer (Afloat) during numerous availabilities and overhaul periods. The perspective of being the “end user” and having to sail with repairs and maintenance selected by decision makers from shore based engineering commands and facility managers. From the perspective of living aboard a ship for several years where repairs and maintenance items were selected to be accomplished by shore commands based on budgetary and facility limitations provides a unique background for examining the Navy’s SR&M program. This viewpoint makes a unique view from the complex system of the Navy’s SR&M program, more specifically with regard to the process of analyzing the ‘how’ and ‘why’ of the selection process for identifying a work package for work to be accomplished or deferred. This author thoroughly enjoyed the research process and results. See the VITA on the last page of this dissertation.

7.3 Implications of the Results

The implications of the results of this dissertation for both research and practice are addressed in this section.

7.3.1 Implications for Research

The results of the research study contribute to existing and future research in several ways. First, the study provides evidence that a systems-based project risk management and life-cycle assessment framework for the ship repair and maintenance selection process can improve ship readiness and reduce ship life time costs. The study provides the evidence that a systems-based process used to develop the framework for the Navy's SR&M program may be reliably applied to other complex systems. This is important in that the framework is general due to the fact that the theory represents a large variety of facts.

The development of a framework requires the same rigor as the development of a theory, and must be based on scientific inquiry. Failure to base the development of a framework on rigorous research may limit the utility of the framework by failing to include relevant data or exclude irrelevant data. The use of a formal method for the development of a framework, based on systemic principles, ensures that the framework addresses all of the relevant data.

Secondly, the study provides a framework which may be used to conduct additional research on complex system projects. The ability to expand the research to projects with different characteristics is an immediate objective for generalization of other research efforts, extending its applicability and utility.

Thirdly, the research makes a significant contribution to the body of knowledge on qualitative research in engineering management of complex systems.

7.3.2 Implications for Practice

The results of the research study contribute to the practice of project risk management and engineering management of complex systems. The Project-Risk Management Life-Cycle Framework drawn from the ship inspection, repair, and maintenance may be a usable approach in other areas of engineering management. Decisions based upon political decisions notwithstanding, a validated PRMLC Framework may prove highly successful in times of severe budgetary constraints. The framework provides an engineering management systems-based structure that may be used for any complex organizational system.

7.3.3 Potential Publications

The IEEE Explore Engineering Management Journal, The U. S. Naval Institute's Proceedings, ASNE's Naval Engineers Journal, ASEM's Engineering Management Journal, INCOSE's Journal of Systems Engineering, PMI's Project Management Journal, and other publications such as the Maritime Journal. Topics such as Why look at project-risks? From the perspective of Project Management," the addition of a risk assessment is considered as value added, necessary and required, but often viewed as a non-value added decision making process. However, the extent to which a project may fail to meet specifications or deadlines is statistically greater than not. Risk management may be defined as “a procedure to control the level of risk and to mitigate its effects.” (Uher & Toakley, 1999) The imposed risks are identified and addressed through a project or program management process by systems engineers and program managers, with overall responsibility to the yard and NAVSEA offices. Various authors have suggested using risk management as a continuous process improvement (CPI) tool, called value stream mapping (VSM), which is aimed at increasing the effectiveness of risk management. As an aside, the evaluation of risk and the probabilities are subjective and assumption laden and “based on theoretical models, whose structure is subjective and assumption laden, and whose inputs are dependent on judgment.” (Slovic citation in Botterill, 2004)

This study proposes to identify the need to assess risk-management from a life-cycle perspective. The U. S. Navy manages the coordinated effort for shipbuilding, repair, and maintenance of ships and submarines in the fleet. Risk assessment from a life-cycle approach may aid in the process towards eliminating waste and optimizing the utilization of resources. A brief look at the risk of lost time due to less than optimum procedures and requirements shall be undertaken towards investigating the gap in performance. Risks across projects establish GAP in the literature would be valuable to study. The current Navy management system and process for scheduling ship inspections, repairs, and maintenance items within a risk managed and life cycle assessed periodicity for the express purpose of maximizing operational availability and minimizing total ship cost.

Specific potential publications and papers include:

- The Application of Risk Management and Life Cycle Application for System Projects, EMJ.
- Stakeholder Participation in the Risk Management and Life Cycle Process for Complex Systems, EMJ.
- Philosophical Application in Using a Risk Management and Life Cycle Assessment, Risk Analysis.

7.4 Contributions of the Research

7.4.1 Further generalization of research contributions:

The realignment of decision making functions and communication presented in Figure 24 can be generalized for systems other than Navy' SR&M, such as manufacturing, service, private, government, etc.. This generalization can be summarized as:

1. Recognizing that objectives of various decision makers and organizations (i.e. elements) within a system of systems (SoS) does not necessarily support a life-cycle or systems risks approaches

2. Nonetheless, a fairly-evolved SoS, such as that in the Navy's SR&M, can have at least one element that supports such approaches (i.e. SURFMEPP)

3. Once this element is identified, an incremental progress towards implementing life-cycle and systems risks approaches in a SoS can be affected by realigning linkages of communication and decision making.

In essence, this dissertation presents a framework that can be generalized and extended to other SoS organizations, such as HLS, NASA, GE, VDOT, Norfolk Southern Railroad and others, who may benefit from having life-cycle and systems risks approaches implemented in their organization

The first goal of the research is to develop a theoretical framework for managers in the shipbuilding and maintenance. The conjecture regarding a holistic, structured, and systemic framework for improving decisions by managers-in-crisis in the shipbuilding and repair industry by utilizing an organizational knowledge management system is the object of the methodology. The research developed a project-risk and life cycle management framework that improves the Navy's ship repair and maintenance (SR&M) process so ships may reach their operational 35-year service life. This phase was qualitative and relied on both methodologies to triangulate a valid and workable framework.

To the practice of SR&M the proposed framework will:

- Contribute toward the objective of ships to be fully operational for a 35 year service life.
- Contribute in controlling total ship SR&M costs during the 35 year service life.

The theoretical perspectives included: (1) transferability of project risk management aspects from the shipbuilding, repair, and maintenance to other industries; and (2) the application of a life-cycle approach of assessing project-risk management in analyzing multi-project risk management techniques.

To the body of knowledge:

- Unified framework for risk and life-cycle approach to maximize system(s) operability.

- Realization of decision-based necessity to minimize system(s) risk and/or uncertainty.
- Implementation of risk management **across** system boundaries.

7.5 Future Research Recommendations

One role of a rigorous scholarly research is to provide paths for further research. This section considers the current state of the systems and project-risk management and life cycle applications for complex systems, their bodies of knowledge and relationships to research findings. The development and articulation of the concept of a systems-based project risk management with a life-cycle assessment framework provides fertile areas for additional research. There may be many other areas yet to be addressed by additional rigorous research. The following areas for future research are recommended.

7.5.1 Future Research for Theoretical Issues

The research presented a systems philosophy that was a product of the worldview of the researcher and the focus of the research. The research addressed the requirement for a holistic approach to the complex system, the Navy's ship inspection, repair, and maintenance program. A system-based framework was developed to address the complex processes required to develop a better way to determine which ship's inspection, repair and maintenance project/job/work items are to be completed to improve a ship's 35-year service life operationally and total ship cost. The processes were managerial and procedural and included a rich contextual environment that significantly affected their framework outcome. Specific future research issues may include:

➢ Decision making for large complex organizational systems.

- Process improvement of organizational structures in NAVSEA.
- Process improvement of inter-organizational functions..

Much of the discussion in the literature and data presented in the research study was focused upon trying to develop a framework to improve a ship's 35-year service life operationally and total ship cost by transforming the complex system project management process. Future research should include bringing risk management and life-cycle assessment into the engineering management of complex systems. The following areas for future research are recommended.

- Multi-criteria PRM and LCA.
- Statistical evaluation of the proposed framework implementation.
- Operational evaluation of the proposed framework implementation.
- Modeling of the proposed framework.

Further, the established validity of the project-risk and life-cycle management approach of the framework could include the additional domains of:

- Project life cycle costing by resource optimization.
- Life cycle programmed scheduling.
- Risk management reliability design.
- Life cycle-based risk management.
- Risk management process to system(s) development.

7.5.2 Future Research for Methodological Issues

The case study method was employed to build a framework and was validated by subject matter experts providing expertise on the validity of the proposed framework. This provides many future research opportunities for problematic framework issues.

The case study method also provides opportunities in the ship repair and maintenance field. In the last year, the Navy has changed the organizational structure of the ship repair and maintenance by adding and redirecting efforts of several commands, and changing some reporting requirements and chain-of-command links.

The subject matter expert substantiation of the proposed framework validated the theory and practice, but there are additional domains and areas available for investigation.

7.6 Summary

This chapter presented the limitations of the study, the implications of the results, and recommendations for future research. Further research directions were proposed with emphasis in the following areas: (1) Philosophical concepts that address the use of a framework to be used for any complex systemic organization and the theoretical definition for project risk management and life-cycle assessment; and (2) extension of work on the Navy's ship repair and maintenance program by applying a project risk management and life cycle assessment.

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APPENDICES

APPENDIX A: KEY DEFINITIONS

Complex System

"A complex system is a system composed of interconnected parts that as a whole exhibit one or more properties (behavior among the possible properties) not obvious from the properties of the individual parts." (Joslyn & Rocha, 2000, p. 70-79)

Decision Analysis

"… is an attempt to bring analytic methods to bear on the difficult problem of decision-making under risk." (Gibson, Scherer, & Gibson, 2007)

Decision Making Process

"When decision making is described as an activity, the relation between time and decision making can be seen as a special case of the relation between time and actions. This relation can be expressed by the contextual control model (COCOM;cf. Hollnagel and Woods, 2005), which describes how the ability to maintain control depends on the controlling system's interpretation of events and selection of action alternatives (Figure 1.1). At the heart of the model is a cyclical relation linking events, intentions, and actions where in particular the two arcs called evaluating/assessing the situation and choosing what to do are relevant for the present discussion." (Cook, Noyes, & Masakowski, 2007)

Life Cycle

"Every system or product life cycle consists of the business aspect (business case), the budget aspect (funding), and the technical aspect (product). The systems engineer creates technical solutions that are consistent with the business case and the funding constraints. System integrity requires that these three aspects are in balance and given equal emphasis at all decision gate reviews." (DoD, 2001)

"The life cycle point of view emphasizes that system analysis and design must consider matters such as system maintainability, periodic system upgrades, decommissioning, dismantling, and replacement." (Gibson, et al., 2007)

Life Cycle Planning

"The project manager must consider the project over its entire life cycle, including its termination, removal, and replacement. (Gibson, et al., 2007)

Project

"An endeavor with defined start and finish dates undertaken to create a product or service in accordance with specified resources and requirements." (ICOSE, 2006)

"… a set of activities with a defined start point and a defined end state, which pursues a defined goal and uses a defined set of resources." (Slack, Cambers, & Johnston, 2007)

"A project is an endeavor that has a definable objective, consumes resources, and operates under time, cost, and quality constraints." (Kerzner, 2004)

Project Management

"A controlled process of initiating, planning, executing, and closing down a project." (Valacich, 2004)

"… can be defined as the planning, scheduling, and controlling of a series of integrated tasks such that the objectives of the project are achieved successfully and in the best interest of the project's stakeholders." (Kerzner, 2004)

"Succinctly, a project is an organized endeavor aimed at accomplishing a specific no routine or low-volume task." (Shtub, 2005)

Risk

"…is defined as a measure of the probability and severity of adverse effects [Lowrance, 1976]." (Haimes, 2004)

"In project management, it is common to refer to very high levels of uncertainty as sources of risk. Risk is present in most projects, especially in the R&D environment. Without trying to sound too pessimistic, it is prudent to assume that what can go wrong will go wrong. Principle sources of uncertainty include random variations in component and subsystems performance, inaccurate of inadequate data, and the ability to forecast satisfactorily as a result of lack of experience." (Shtub, 2005)

Risk Management

"The term management may vary in meaning according to the discipline involved and/or the context. Risk is often defined as a measure of the probability and severity of adverse effects. Risk management is commonly distinguished from risk assessment, even though some may use the term risk management to connote the entire process of risk assessment and management". (Haimes, 2004)

"Risk management is an organized means of identifying and measuring risk, and developing, selecting, and managing project options for handling those risks." (Kerzner, 2004)

System

"A system is a set of elements so interconnected as to aid in driving toward a defined goal." (Gibson, et al., 2007)

System of Systems (SoS)

"... are defined as an interoperating collection of component systems that produce results unachievable by the individual systems alone." (Krygel, 1999, p. 33) (INCOSE, 2006, p. 2.2)

Systems Engineering

Defined by INCOSE "as an interdisciplinary approach and means to enable the realization of successful systems." (INCOSE, 2006)

Systems Practice

"...implies using the product of this thinking to initiate and guide actions we take in the world." (Checkland, 1999)

Systems Principles

"Systems knowledge, in the scientific hierarchy that includes laws, principles, theorems, hypotheses, and axioms. (see Skyttner, 2001 and Clemson, 1991)

Systems Thinking

"...makes conscious use of the particular concept of wholeness captured in the word system, to order our thoughts. (Checkland, 1999)

APPENDIX B: LITURE REVIEW LIST

Source	System Mgmt	Pgm Mgmt	Proj Mgmt	Risk Mgmt	Know Mgmt	Decision Mgmt	Cost Mgmt	Ship Repair & Maintenance	Life Cycle	Ship Svc LIfe	Mission Reqmts	Ship Repair & Maintenance
Andrews et al (2004)				x				x				
Arena et al (2004)	x						x		x			x
Ari et al (2008)								x				
Ayyub et al (1993)				x								
Bahill & Botta (2008)	x											
Bolles (2003)				x		x						
Booker & Meyer (1999)												
Boudreau & Naegle (2005)		x					x		x		x	
Brown & Salcedo (2003)	x		x				x		x		x	
Cabano (2005)				x								
Caddell et al (2005)				x		x						
CBO Testimony (07/24/07)							x				x	
Clark & Besterfield-Sacre (2009)				x								
Clarke (1999)			x									
Conrow (2003)	x			x								
Cooke-Davies (2001)			x			x			x			
Cowell et al (2002)				x		x						
Cox (2008)				x								
Cox (2009)				x								
CRS Report for Congress [OPNAV N8F] (2008)	x						x			x	x	x
Daniels & LaMarsh (2007)	x		x									
Dasher (2008)	x	x						x			x	
Dean et al (2008)						x						
Dillon et al (2003)			x	x								
DoD Directive 2060.1	x	x									x	
DoD Directive 2060.1	x	x										
DoD Directive 2311.01E	x	x					x					
DoD Directive 2311.01E	x	x					x				x	
DoD Directive 4630.05	x	x			x				x			

Source	System Mgmt	Pgm Mgmt	Proj Mgmt	Risk Mgmt	Know Mgmt	Decision Mgmt	Cost Mgmt	Ship Repair & Maintenance	Life Cycle	Ship Svc LIfe	Mission Reqmts	Ship Repair & Maintenance
DoD Directive 5000.01		x					x		x			
DoD Directive 5000.2	x	x		x	x		x					
DoD Directive 5000.60	x	x		x			x					
DoD Directive 5010.31	x						x	x				
DoD Directive 5030.8	x	x						x				x
DoD Directive 5030.9	x	x										x
DoD Directive 5100.01	x										x	
DoD Directive 5134.3	x	x					x				x	
DoD Directive 8500.01E	x				x							
DoD MIL-STD 882				(x)								
Elonen & Artto (2003)		x	x									
Eve (2007)			x									
Freimut et al (2005)			x						x			
GAO Report to Congress (2005)									x			
GAO Report to Congress (052201)							x		x		x	
GAO Report to Congressional Committees (November 2005)											x	
Garvey & Pinto (2009)	x			x								
Gharajedaghi (2004)	x										x	
Gilmore and Labs (2007)							x					
Goddard, et al (dnloaded June 9, 2008)	x	x		x			x	x		x		
Gratsos & Zachariadis (2008)							x		x	x		x
Haimes (2004)	x	x		x	x				x			
Haimes (2009)	x											
Hanish et al (2009)			x		x							
Henry & Haimes (2009)				x					x			
Hofstetter et al (2002)				x								
Holmes et al (2009)				x								

Source	System Mgmt	Pgm Mgmt	Proj Mgmt	Risk Mgmt	Know Mgmt	Decision Mgmt	Cost Mgmt	Ship Repair & Maintenance	Life Cycle	Ship Svc LIfe	Mission Reqmts	Ship Repair & Maintenance
Hussain & Wearne (2005)			x					x		x		
IBM 2006			x				x			x		x
Johnson (2006)			x			x	x					
Kalling (2003)					x	x						
Karanki et al (2009)												
Keating et al (2003)	x											
Keating et al (2008)	x											
Kerzner (2004)		x	x									
Kimbrough & Componation (2009)				x				x	x	x	x	
Koenig et al (2008)	x	x					x		x	x	x	x
Kolltveit et al (2005)			x									
Kotnour & Landaeta (2003)					x							
Lowrance (1976)				x					x			
Manufacturing: A Report on the Industry (June 2004)							x					
Mathews et al (2002)				x		x						
Mausser & Rosen (1999)				x		x						
McCumber & Sloan (2002)	x								x			
Mead et al (2000)						x						
Meckler (2005)												
Morgan et al (2000)				x								
Morris & Jamieson (2005)		x	x	x								
National Defense University (2004)							x					
NAVSEA Shipyard Compliance Items (2009)			x									

Source	System Mgmt	Pgm Mgmt	Proj Mgmt	Risk Mgmt	Know Mgmt	Decision Mgmt	Cost Mgmt	Ship Repair & Maintenance	Life Cycle	Ship Svc LIfe	Mission Reqmts	Ship Repair & Maintenance
NAVSEA Standard Item Numerical Index FY-09			x									
NISTIR 6917 (Nov 2002)												
Olsen et al (1998)				x				x		x	x	
OPNAV CRS Report to Congress 2008	x										x	
OPNAV Instruction 3000.15								x	x		x	
OPNAV N43B Report (2009)							x	x				
O'Rourke CRS Rpt for Congress (2008)	x						x		x			
Owens (1997)				x		x						
Padilla et al (2009)	x					x						
Palomo et al (2007)			x	x			x					
Parnell et al (2008)		x										
Peltier (2005)				x		x						
Petroski (2005)						x						
Pinto & Pathak (2008)				x		x	x					
Pinto et al (2006)	x			x								
Pinto et al (2006a)				x		x						
Powell & Buede (2006)	x		x			x						
Preiholt (2002)						x						
Roberts et al (2003)			x								x	
S&T for Naval Warfare 2015 - 2020 (Aug 2005)							x		x		x	
Sargent et al (2006)			x									
Seiler (1990)				x								
Seyedhoseini et al (2008)				x								
Shtub & Globerson (2005)			x									

Source	System Mgmt	Pgm Mgmt	Proj Mgmt	Risk Mgmt	Know Mgmt	Decision Mgmt	Cost Mgmt	Ship Repair & Maintenance	Life Cycle	Ship Svc LIfe	Mission Reqmts	Ship Repair & Maintenance
Soderlund (2002)			x									
Starr (2000)	x			x		x						
Steele et al (2009)								x			x	
Sydow (2008)									x		x	x
The Maritime Strategy, Fleet Response Plan & Maintenance Contributions (2008)							x		x			x
U S House of Representatives Systems Development Life-Cycle Policy Final 3/24/99	x			x			x		x			
U.S.House of Representatives (1999)	x			x					x			
U.S.House of Representatives Systems Development Life-Cycle Policy 03/24/99	x			x					x			
US House of Representatives Systems Development Life-Cycle Policy 03/24/99	x			x					x			
US HR Syst Dev Life-Cycle Policy (1999)	x			x			x		x			
Wideman (2004)			x									
Williams (2005)	x		x									
Wysocki (2007)			x					x			x	
Yardley et al (2006)	x						x				x	x
Yeo (2002)	x		x									
Young (2004)			x									
Zwikael & Gonen (2007)			x	x								

APPENDIX C: INDUSTRY PRACTITIONER ASSESSMENTS

INTRODUCTION

This appendix presents an industry assessment of the risk and life cycle analytic methods developed in this dissertation. The objectives of this assessment were to:

(a) Obtain feedback from the ship repair and maintenance community on the logic and efficacy of the proposed framework.

(b) Ascertain the relevance of this research to real-world practice in complex engineering systems and enterprises.

The industry assessment was performed using qualitative research design principles and practices as described in Creswell (2003) and Marshall & Rossman (1999). The assessment method falls broadly into the case studies approach, the exploratory investigative technique that is "fundamentally interpretive." (Creswell, 2003)

Qualitative data was obtained from a survey defined by nine open-ended, non-directive questions (Mariampolski, 2001). This survey enabled and permitted the findings to emerge through the assessment process. Face-to-face interviews allowed further probing of the data after the survey was completed by each respondent.

This researcher started with answers and formed questions throughout the research process. This inductive analysis of respondent data provided a basis of the analysis process, consisting of the four steps identified in Figure 27 below.

Step 1	**Design and Deliver Open-Ended Questions to Interviewees**
	Table 7: Ship Repair & Maintenance Survey Questions
Step 2	**Analyze Data from Interviewees to form Themes and/or Categories**
	Table 8: Industry Respondent Summary Questions
	Table 9: Industry Question Alalysis Cards
Step 3	**Identify Broad Patterns and Generalizations from Themes**
	Table 10: Rated Industry Assessment Alalysis by Question
	Table 11: Survey Response Analysis by Question
Step 4	**Draw Conclusions**
	Table 12: Survey Response Analysis

Figure 27: The Industry Assessment Inductive Analysis Approach

The first step was the design and delivery of the survey instrument to identified industry participants. As previously mentioned, nine open-ended questions were defined and are listed in Table 7: SR&M Industry Survey Questionnaire.

The second step involved an analysis of survey returns with the aim of inductively establishing themes and/or categories that characterized the responses from each respondent.

The third step analyzed themes derived from the preceding step to look for broad patterns or generalizations that might be gleaned from the data.

The fourth and last step fuses the findings into a set of overall conclusions about the relevance, logic, and efficacy of the proposed framework in this dissertation research from a practical real-world project-risk and life cycle assessment within the engineering management and systems engineering perspective.

1	**What will be the short term impact on the ship availability process?**
2	**What will be the long term impact on the ship availability process?**
3	**What will be the scheduling impact on facilities/workforce for availabilities?**
4	**What will be the scheduling impact on ship deployments?**
5	**What will be the scheduling impact on the Total Ship System Readiness Assessment program?**
6	**How will the new framework affect the Reliability-Centered Maintenance program?**
7	**Will the proposed framework benefit a ship reaching its 35-year service life?**
8	**Will the proposed framework contribute to better decision making in determining which repairs, maintenance, and inspections are to be accomplished during a scheduled availability?**
9	**What concerns do you foresee in the Navy implementing the proposed framework?**

Table 7: Ship Repair & Maintenance Industry Survey Questions.

Participant Selection and Qualifications

Participant selection for the industry assessment followed guidance in the literature on criteria for identifying experts. Research by Ayyub (2001) and Edwards (2003) address this topic, and are summarized as follows:

Ayyub (2003) defines an expert as a “very skillful person who had much training and has knowledge in some special field.” He also emphasized the importance that an expert’s knowledge be publicized at a level recognized by others in the community. This is consistent with studies according to Edwards (2003), who identifies experts as persons who have attained: academic degrees, training, experience, publications, position or rank, or attained special work-related appointments, studies, or assignments.

The criteria for selecting experts may be partially derived from work by Ayyub (2003). He indicates that no single criterion should be used as a selection basis or disqualifier for the identification of an expert. It is logical to say that a number of years of experience, educational, and cognitive skills may provide the criteria to be used in the selection process.

Shanteau (1992) indicates that judgment and decision research has shown that experts make flawed decisions due, in part, to the biasing effects of judgmental heuristics. He further indicates that cognitive science research views experts as competent and different from novices in nearly every aspect of cognitive functioning. Shanteau (1992) proposes that both analyses are correct depending on these five components:

1. Sufficient knowledge of the domain.
2. The psychological traits associated with experts.
3. The cognitive skills necessary to make tough decisions.
4. The ability to use appropriate decision strategies.
5. A task with suitable characteristics.

Shanteau's 2001 research recognizes that "discrimination and consistency" are two critical attributes in selecting an expert. Discrimination refers to the "ability to differentiate between similar but not identical cases and is the hallmark of expertise. It has been determined that experts perceive and act on subtle distinctions that others miss. Discrimination refers to a judge's differential evaluation of different stimulus cases."

(Shanteau, 2001) Consistency reflects “within-person reliability; it refers to a judge’s evaluation of the same stimuli over time; inconsistency is its complement.” (Shanteau, 2001)

The participants selected for the industry assessment/validation met or exceeded the criteria identified previously. The relevant domains for this research are:

- ✓ academic degrees
- ✓ training
- ✓ experience
- ✓ position or rank
- ✓ special work-related appointments

Qualification statements for the above domains were written and are shown next. With these experts, the validation of the proposed framework can be presumed to be meaningful according to previous definitions of experts.

Systems Engineering (Project Manager) Qualification

A systems engineer is qualified to participate in this interview process if he/she has at least 10-years of successful experience in engineering systems management or development. This should include technical leadership with engineering management experience of a comparable level with technical leadership responsibilities. A key qualification is leadership experience that ranges from traditional systems to complex engineering systems, to include systems of systems and enterprise systems. One or more technical degrees are preferred in engineering management or a closely relevant field.

Risk Management (Program Manager) Qualification

A risk/program manager is qualified to participate in this interview process if he/she has at least 10-years of successful experience in the design, implementation, and applying risk to ship repair and maintenance availability work and inspection items. This should include engineering management leadership with risk management, ranging from project to inspection of ship systems and machinery. The engineering management experience at a comparable level with technical leadership responsibilities. A key qualification is leadership experience that ranges from traditional systems to complex engineering systems, to include systems of systems and enterprise systems. One or more technical degrees are preferred in engineering management or a closely relevant field.

Life Cycle Manager Qualification

A life-cycle/program manager is qualified to participate in this interview process if he/she has at least 10-years of successful experience in the life cycle implications of ship and ship systems design and/or ship operations. This should include the application of life cycle management to maintain periodicity of repairs, maintenance, and inspections for a ship availability period. This should include engineering management leadership and management experience at a comparable level with technical leadership responsibilities.

SUMMARY OF TABLE DESCRIPTIONS

Before presenting the assessment summary findings, the tables created from the industry expert survey are explained below:

Table 8: Industry Respondent Summary Questions

Table 8 is a summary analysis by question with respondent agreement of each questions' relevance to the proposed SR&M framework by phrase similarity per respondent. The information elements originate from each of the respondent's raw data.

Table 9: Question Analysis Cards

Table 9 is a set of nine sheets, with one sheet for each question. The information elements are defined as follows. The *categorical analysis* section results from an inductive categorical analysis of the respondent summaries. The *summary* is an overview of the analyses. The *text analysis* section is the result of a discourse analysis of the respondent text. Discourse analysis is a method to conduct a quantitative text analysis of the information provided by respondents. The discourse analysis looked at two areas. These areas are *most frequent words* and *phrase prominence*. The area of *most frequent words* refers to the most recurrent relevant words reported across all respondents. The area *phrase prominence* refers to the most recurrent relevant phrase reported across all respondents.

Table 10: Related Industry Assessment Analysis by Question

Table 10 is a summary analysis by question with respondent agreement of each question's relevance to the proposed SR&M framework by phrase similarity by respondent. The information elements originate from the respondents raw data.

Table 11: Survey Response Analysis by Question

Table 11 is a summary analysis by question from each respondent. Each phrase was assessed and evaluated as being positive, neutral, or negative with respect to the implementation of the proposed SR&M framework. The information elements originated from respondent raw data.

INDUSTRY FINDINGS

Key findings from the industry assessment are discussed and summarized by tables:

Table 8: Industry Respondent Summary Questions

Question 1	Respondent 1	Respondent 2	Respondent 3	Respondent 4
What will be the short term impact on the ship availability process?	Short-term impact is aligned to the budget process SURFMEPP had significant influence on the PR11 and POM12 budget process We indentified missing or under-stated requirements that amounted to significant increases in CNO maintenance budgets Specifically, twenty-eight DDGs with CNO availabilities in FY12 will benefit from technically-grounded Baseline Availability Work Packages (BAWPs) which includes a robust process for managing work deferral and the associated technical, financial, and operational risk of deferral	Short-term impact is that current readiness could possibly be lessened due to completing deferred inspections, repairs, and maintenance work (More time in maintenance)	Short-term impact will improve work package planning by SURFMEPP and execution by RMCs Technical requirements will be better defined and integrated to ensure adequate multi-year budget projections are well developed and technically founded	CMAV assessments will increase Identified life cycle items will be added to availability work package Initial inspection, repair and maintenance costs will increase Initial requirements will demand increased man-hours

Question 2	Respondent 1	Respondent 2	Respondent 3	Respondent 4
What will be the long term impact on the ship availability process?	Long-term impact will include all classes of surface ships in a common end-to-end maintenance process with well-define requirements that ensure our ships are capable of achieving Expected Service Life (ESL)	This proposed framework would stabilize the SR&M process This process would make the availability planning work execution discipline repeatable with well-define requirements that ensure ships achieving their Expected Service Life (ESL)	Long-term impact will include all surface ship BAWPs as studies based on Technical Foundation Papers for justification and readiness implications The technical foundation papers will incorporate the rigor of the technical review and validation of maintenance and modernization requirements into a long term planning and execution life cycle management strategy for surface ships The aggregate of all of these efforts will generate better defined and justified requirements and resources to improve ship maintenance availabilities	Identification of what needs to be accomplished will require more man-hours and require increases in the duration of CNO availability periods

Question 3	Respondent 1	Respondent 2	Respondent 3	Respondent 4
What will be the scheduling impact on facilities & workforce for availabilities?	We anticipate more work will be executed in depot availabilities Scheduling should be seamless and in line with current processes We do anticipate a more active role in identifying the right duration of shipyard periods required We are also positioned to conduct analysis on current operating cycles and how efficiencies might be gained by changing operating cycles Submarine and carrier communities have come through similar studies	In the near term there is potential for an increased volume of private sector work in their yards and facilities Standardizing the process will increase the predictable work load, which will permit long term savings in ship repair and maintenance	If all of the pieces of these efforts come to fruition (examples better requirement definitions, technical based requirements, proper planning and proper resourcing of maintenance and modernization requirements), I anticipate more work will be executed during availabilities by government planners and workers Private and public sector workers and facilities will experience increases in scope of work and increased funding for ship repair and maintenance	Short term increases in workload on government and commercial resources Long term advantages will be better managed availabilities, thereby reducing the risk of ship system, component, and equipment failures, increasing ship service life, permitting unencumbered underway operations, and reducing manpower requirements

Question 4	Respondent 1	Respondent 2	Respondent 3	Respondent 4
What will be the scheduling impact on ship deployments?	Maintenance supports operations Our products must support the operational commanders There will be no impact on deployment schedules We strive to maximize Ao by providing a balance maintenance approach that balances current readiness with future service life	There will be no impact on deployment schedules In long term, stabilizing availability planning and execution will reduce churn on the maintenance phase and provide more predictable results in support of the operational commanders	Since ship schedules are defined in advanced, the overall process should not affect ship schedules What these efforts will yield is better integration of maintenance and modernization work to minimize or eliminate any adverse impact to ship schedules due to late discovery of work and proper execution of planned work The ship operating cycle has been extended from 18 months to 27 months Ship deployments are fixed and are the limiting factor affecting scheduled availability periods for the accomplishment of inspections, repairs and maintenance work packages USFFC and SURFMEPP work hand in hand to meet ship needs, as	It is anticipated framework will not impact ship deployment schedules

Question 5	Respondent 1	Respondent 2	Respondent 3	Respondent 4
What will be the scheduling impact on the Total Ship System Readiness Assessment program?	TSRA policy is still under development. I would anticipate more structured visits in port as well as underway. There is the potential for some short-term availability issues of forces. The maintenance community needs the time to put subject matter experts on board ship to assess critical ship systems.	TSRA policy will formalize the requirements within the cycle for assessments. Standardizing assessment execution in support availability execution.	TSRA program is pretty well defined. TSRA events are being scheduled into the ship's FRP cycle. The biggest challenge will be in obtaining the necessary resources to execute TSRA and not the scheduling of the event: TSRA-1 (-240 days before deployment); TSRA-2 (0 + ?? days after deployment); TSRA-3 (-90 to -180 days to deployment); Windows of opportunities depend on the ship's input, documentation, and control of its CSMP for planning for the next work period. The maintenance community needs the time to put personnel onboard the ship to assess critical ship systems.	The proposed framework proposal will yield positive results by reducing system, equipment, and component downtimes, reducing time based maintenance work items, and will improve the conditioned based maintenance process.

Question 6	Respondent 1	Respondent 2	Respondent 3	Respondent 4
How will the new framework affect the Reliability-Centered Maintenance program?	Our Integrated Class Maintenance Plans (ICMPs) are supported by RCM models and requirements. There will be no impact to RCM program.	TSRA policy will formalize the requirements within the cycle for assessments. Standardizing assessment execution in support availability execution.	The proposed framework will compliment the RCM model and should be endorsed. The Integrated Class Maintenance Plans (ICMPs) is supported by RCM models and requirements.	The proposed framework will positively impact the Reliability Centered Maintenance program.

Question 7	Respondent 1	Respondent 2	Respondent 3	Respondent 4
Will the proposed framework benefit a ship reaching its 35-year service life?	ESL is core mission for SURFMEPP. Our goal is to ensure technically required maintenance is accomplished that supports a Long Range Maintenance Schedule with the right budget needed for execution of those requirements.	The Integrated Class Maintenance Plans (ICMPs) are supported by RCM models and requirements. The proposed framework will have no impact on the RCM program.	Absolutely. The goal is to ensure technically required maintenance is accomplished that supports a Long Range Maintenance Schedule with the right budget needed for execution of those requirements.	The proposed framework should allow the ship to meet its 35-year service life.

Question 8	Respondent 1	Respondent 2	Respondent 3	Respondent 4
Will the proposed framework contribute to better decision making in determining which repairs, maintenance, and inspections are to be accomplished during a scheduled availability?	Yes. We are the TYCOMs advocate for budgets needed to maintain our ships to reach expected service life. We are also NAVSEAs advocate to ensure that technically required work is accomplished. Where operations take priority over maintenance, the Navy now has a Command that can capture deferred work. In addition, if Navy deems the technical risk too high, we provide the services as the "honest broker" to ensure risk and requirements are in balance.	Yes. As the TYCOMs advocate for budgets needed to maintain our ships and NAVSEA advocates the technically required work, ships should be able to reach their expected service life. The framework provides the right structure to execute the new end to end process.	Absolutely. SURFMEPP will be able to capture deferred work and determine if the technical risk is too high, notify NAVSEA 05 and the TYCOM for guidance to ensure risk and requirements are in balance.	Yes, and will permit better identification of system, equipment, and component risks.

Question 9	Respondent 1	Respondent 2	Respondent 3	Respondent 4
What concerns do you foresee in the Navy implementing the proposed framework?	I don't think SURFMEPP can be the decision-maker in this process. We manage the process and provide an "honest broker" approach in uniting the TYCOM and NAVSEA. Ultimately, it is the TYCOMs responsibility to train, man, and equip ships that are true warships ready for tasking. That is a Title X responsibility. Yet at the same time, SURFMEPP has an obligation to inform NAVSEA when technical requirements are "requested" to be deferred. The technically-warranty engineers at NAVSEA can then hold the TYCOM accountable if they consider the technical risk "too great" to ensure safe operation and long term employment of warships.	Stability in funding to support ship inspection, repair, and maintenance and maintaining requisite shore based resources to execute maintenance. SURFMEPP has an obligation to inform NAVSEA when technical requirements are "requested" to be deferred. The technical warrant holder at NAVSEA 05 will provide oversight to the TYCOM to ensure the technical risk is accurately understood to ensure safe operation and long term employment of warships. TYCOM still retains decision authority for operational risk decision making. SURFMEPP can provide an "honest broker" approach for ship inspections, repairs, and maintenance between and	The limiting factor is that there will not be enough funding to carry out the needed ship inspections, repairs, and maintenance work for each ship.	Impediments to its acceptance may be due to current political winds and budgetary processes. Changing leadership and management views inside the DoD, such as short term or long term visions of fleet inspection, repair and maintenance goals may preclude its acceptance and implementation.

Table 8: Industry Respondent Summary Questions

This table organized each respondent's raw data comments for by question, with one page per question containing the responses of the four SMEs. This assembly by question assisted in the process of identifying each respondent's unique term(s) and/or phrase(s), to be further analyzed in Table 9: Question Analysis Cards, Table: 10 Industry Assessment Analysis by Question, and Table 11: Survey Response Analysis by Question.

Table 9: Question Analysis Cards

Table 9: Question Analysis Cards
Question 1: What will be the short term impact on the ship availability process?

Categorical Analysis

Scope

Respondents directly or implicitly indicated that the complexity of the current ship repair and maintenance (SR&M) process being altered to a project-risk and life cycle based decision making ship repair process posed management of resources challenges. The positives are the ability to conduct ship life cycle inspections as a priority and thus making ship service life more possible but the challenges would strain current resources as a tradeoff for future resource reductions.

Inspection, Repair and maintenance Scheduling

Respondents cited advantages to the planning of needed life cycle inspections and work items that are deferred due to limitations of resources and availability timelines and job confliction due to overlapping areas of shipboard spaces or dry dock. Dependency relationships were not based on time synchronization of deliveries and footprint, but also funding relations of competing work sponsors (commands). These dependencies exist across the operational and technical political viewpoints across the Navy command structure.

Focused Management Decision Needed

The supporting systems and organizations to the ship repair and maintenance program are yet not directly reporting to the Surface Maintenance Engineering Planning Program (SURFMEPP) Activity, responsible for the ship having a 35-year service life. The main focus of SURFMEPP is to monitor and oversee the availability work package, especially those inspections, repairs and maintenance items that can negatively impact its 35-year service life.

Summary

As described above, respondents cited key short term challenges to implementing this framework to the current ship repair and maintenance process.

Text Analysis of Respondent Narratives

The following are highlights from the text analysis of the narratives for this question:

Most Frequent Words: aligned, technically-grounded, developed, demand, costs, assessments, defined, & improve.

Phrase Prominence: robust process, more time in maintenance, improved work package planning, and better defined, technically founded, assessments will increase, costs will increase, life cycle items, & increased man-hours.

Table 9: Question Analysis Cards
Question 2: What will be the long term impact on the ship availability process?

Categorical Analysis

Scope

Respondents directly or implicitly indicated that the complexity of the current ship repair and maintenance (SR&M) process being altered to a project-risk and life cycle based decision making ship repair process posed management of resources challenges. Conducting ship life cycle inspections if conducted as a priority will make the attainment of the ship service life possible. The long term challenges may be the management, command, and/or political differences of future leaders, which will drive the allocation of resources. The long term expenditure of resources would be lessened due to the timely inspection and repair and maintenance of items, before small problems grow to more costly ones.

Ship Life Cycle Work Priorities

Respondents cited advantages to the planning of needed life cycle inspections and work items that once are routine in the short term, may reduce any deferred work items and minimize future resource allocations, improve availability timelines, and reduce job conflicts of overlapping work and scheduling a dry dock for hull critical systems. Dependency relationships were based on time synchronization of deliveries and funding relations of competing work sponsors (commands).

Focused Management Decision Needed

The supporting systems and organizations to the ship repair and maintenance program should be fully implemented, and the Surface Maintenance Engineering Planning Program (SURFMEPP) Activity be vested with all commands to voice to imperative for each ship reaches its 35-year service life. The focus of SURFMEPP is to monitor, oversee, and recommend items in each ship's CSMP availability work package, specifically those inspections, repairs and maintenance items that may negatively impact its 35-year service life.

Summary

As described above, respondents cited key long term challenges to implementing this framework to the current ship repair and maintenance process.

Text Analysis of Respondent Narratives

The following are highlights from the text analysis of the narratives for this question:

Most Frequent Words: ensure, achieving, stabilize, repeatable, well-define, rigor, validation, modernization, & man-hours.

Phrase Prominence: end-to-end maintenance process, well-defined requirements, stabilize SR&M process, define requirements, validation of maintenance, better defined and justified requirements, increased duration, & more man-hours for availability periods.

Table 9: Question Analysis Cards
Question 3: What will be the scheduling impact on facilities/workforce for availabilities?

Categorical Analysis

Scope

Respondents directly or implicitly indicated that the complexity of the current ship repair and maintenance (SR&M) process being altered to a project-risk and life cycle based decision making ship repair process posed management of resources challenges. The positives are the ability to conduct ship life cycle inspections as a priority and a repeatable process. This will make ship service life more possible and the challenges would be management command and commercial resources and their allocation of available trained personnel, equipment, and facilities. The initial expenditure of resources would be considerable due to the catching up of inspection and repair and maintenance of items requiring a surge of commercial personnel and facilities.

Work Schedule and a "No Deferral" Imperative

Respondents cited the impact on the planning of deferred life cycle inspections, maintenance and repair work items that will be needed in the short term, causing a strain of facilities and manpower. After this initial backlog of inspections and work has been brought into line with life cycle parameters, there should be improved and better managed workloads during ship availability timelines, which would necessarily reduce job conflicts of overlapping work and the scheduling of dry dock facilities. Dependency relationships were based on an initial increase for the first few years of implementation. The coordination of governmental and commercial facilities and synchronization of ship funding relations for competing command interest and priorities may impede progress.

Focused Management Decision Needed

The ship repair system and organizations will need to better manage/coordinate initial increases in ship inspections, repairs and maintenance work. Surface Maintenance Engineering Planning Program (SURFMEPP) Activity was established to ensure a ship's 35-year service life. The organizational challenge will be to schedule deferred work in addition to other required or mandated work items. The focus will be to have every ship attain their full service life.

Summary

As described above, respondents cited key long term challenges to implementing this framework to the current ship repair and maintenance process.

Text Analysis of Respondent Narratives

The following are highlights from the text analysis of the narratives for this question:

Most Frequent Words: seamless, identifying, cycles, efficiencies, standardizing, & predictable.

Phrase Prominence: private sector, long term savings, increase in scope, increased funding, better managed availabilities, reducing the risk, increasing ship service life, & reducing manpower.

Table 9: Question Analysis Cards
Question 4: What will be the scheduling impact on ship deployments?

Categorical Analysis

Scope

Respondents directly or implicitly indicated that the complexity of scheduling of the ship repair and maintenance (SR&M) process shall not interfere with ship operational short term and long range scheduling. Within the limited timelines, the project-risk and life cycle based decision making process will pose management of resources challenges. The positives are the ability to conduct ship life cycle inspections as a priority and a repeatable process. The challenge will to coordinate governmental and commercial facility resources, trained personnel, equipment, and facilities to complete availability times within the scheduled timeframe.

Ship Readiness Absolute

Respondents cited no impact on the scheduling and planning of deferred life cycle inspections, maintenance and repair work items since the ship deployment dates are not negotiable except in extreme circumstances. The completion of the initial backlog of inspections and work to bring ships in line with project risk and life cycle parameters, there should be improved and better managed workloads during ship availability timelines, will take at least one operating cycle (27 months) to complete. Dependency relationships will be based on an initial increase funding at the inception of the framework. The coordination of governmental and commercial facilities and synchronization of ship funding relations for competing command interest and priorities may impede progress.

Focused Management Decision Needed

The ship repair system and organizations will need to better manage/coordinate initial increases in ship inspections, repairs and maintenance work to be accomplished between ship deployments. The organizational challenge will be to schedule deferred work in addition to other required or mandated work items. The proposed framework has the potential to support every ship in attaining their full service life.

Summary

As described above, respondents cited key long term challenges to implementing this framework to the current ship repair and maintenance process.

Text Analysis of Respondent Narratives

The following are highlights from the text analysis of the narratives for this question:

Most Frequent Words: support, impact, stabilizing, execution, advanced, integration, minimize, schedules, & knowledge.

Phrase Prominence: no impact, balanced maintenance, service life, planning and execution, reduce churn, knowledge of work, better planning, & no impact on ship deployment.

Table 9: Question Analysis Cards
Question 5: What will be the scheduling impact on the Total Ship System Readiness Assessment program?

Categorical Analysis

Scope

Respondents directly or implicitly indicated that the Total Ship System Readiness Assessment (TSSRA) will benefit by the added impetus of the project-risk and life cycle management of ship hull-mechanical-electrical (HM&E) work that often is deferred due to a ship's operational schedule. Within the limited timelines, the project-risk and life cycle based decision making process will also cause the management of resources more challenging. The positives are the ability to conduct ship life cycle inspections as a priority and a repeatable process.

Ship Readiness Imperative

Respondents cited the proposed framework will enhance the scheduling and planning of deferred life cycle inspections, maintenance and repair work. The completion of the initial backlog of inspections and work to bring ships in line with project risk and life cycle parameters is and will be the challenge. Dependency relationships for TSRA policy is the prime mover towards ship inspection, repair and maintenance.

Focused Management Decision Needed

The TSRA program and the proposed framework using a project risk and life cycle management (SURFMEPP focused) for selecting ship inspections, repair and maintenance will complement each other as they provide better documentation for the CSMP. This dual perspective will provide a two pronged management for ship inspections, repairs and maintenance. The organizational challenge will be to schedule deferred work in addition to other required or mandated work items.

Summary

As described above, respondents cited key long term challenges to implementing this framework to the current ship repair and maintenance process.

Text Analysis of Respondent Narratives

The following are highlights from the text analysis of the narratives for this question:

Most Frequent Words: structured, assess, formalize execution, scheduled, resources, input, control, positive, & improve.

Phrase Prominence: structured visits, critical ship systems, standardizing assessment, TSRA events, FRP cycle, execute TSRA, documentation in CSMP, control of CSMP, assess critical ship systems, reducing system-equipment-component downtimes, reducing time based maintenance work items, & improve condition based maintenance process.

Table 9: Question Analysis Cards
Question 6: How will the new framework affect the Reliability-Centered Maintenance program?

Categorical Analysis

Scope

Respondents directly or implicitly indicated that the Reliability Centered Maintenance Program (RCM) will benefit by the added impetus of the project-risk and life cycle management of ship hull-mechanical-electrical (HM&E) work that often is deferred due to a ship's operational schedule. Within the limited ship availability periods, the inclusion of deferred work inspections/work items from the project-risk and life cycle based framework will cause an immediate influx of needed work. The result of completing the deferred work will improve the RCM program outcomes by ships being better "fixed" to deploy.

Ship System and HM&E Reliability

Respondents cited the proposed framework will positively impact the RCM program as well as enhancing the scheduling and planning aspects for ship inspections, maintenance and repair work. Dependency relationships for RCM program is the prime mover towards ship inspection, repair and maintenance, and will be enhanced by the proposed framework based project risk and life cycle management and SURFMEPP Activity focused on ensuring the 35-year service life of each ship.

Focused Management Decision Needed

The RCM program and the proposed framework using a project risk and life cycle management (SURFMEPP focused) for selecting ship inspections, repair and maintenance will complement each other as they provide better documentation for the CSMP. This dual perspective will provide a two pronged management for ship inspections, repairs and maintenance. The organizational challenge will be to schedule deferred work in addition to other required or mandated work items.

Summary

As described above, respondents cited key long term challenges to implementing this framework to the current ship repair and maintenance process.

Text Analysis of Respondent Narratives

The following are highlights from the text analysis of the narratives for this question:

Most Frequent Words: no impact, standardizing, & compliment.

Phrase Prominence: availability execution, will compliment the RCM model, & positively impact the RCM program.

Table 9: Question Analysis Cards
Question 7: Will the proposed framework benefit a ship reaching its 35-year service life?

Categorical Analysis

Scope

Respondents directly or implicitly indicated that the proposed framework of the project-risk and life cycle management of ship inspection, repair, and maintenance for hull-mechanical-electrical (HM&E) work will positively increase the chances of a ship reaching its 35-year service life. The result of completing previously deferred work will also enable ships to deploy with a better readiness M- rating.

The 35-year Service Life Imperative

Respondents cited the proposed framework will positively impact the attainment of each ship's 35-year service life. Dependency relationships for the proposed framework based project risk and life cycle management with SURFMEPP Activity being the prime influence towards scheduling ship inspections, repairs, and maintenance for an availability period. The SURFMEPP Activity is the ideal command to influence other organizations in the attainment of a 35-year service life for each ship.

Risk Analytic Methods Integrated with Life Cycle Engineering Process

The proposed framework of the project-risk and life cycle management will be a unique perspective (managed by SURFMEPP) in selecting which ship inspections, repair, and maintenance will be accomplished in a ship's availability period. This perspective will provide management addressing the overriding necessity to attain a 35-year service life. The organizational challenge will be to schedule the life cycle based work and any other required or mandated work deemed necessary by other commands.

Summary

As described above, respondents cited key long term challenges to implementing this framework to the current ship repair and maintenance process.

Text Analysis of Respondent Narratives

The following are highlights from the text analysis of the narratives for this question:

Most Frequent Words: mission, execution, scheduling, absolutely, & supports.

Phrase Prominence: core mission, no impact on RCM, long range maintenance schedule, integrated class maintenance plans (ICMP), supported by RCM models, right budget, & ship to meet its 35-year service life.

Table 9: Question Analysis Cards

Question 8: Will the proposed framework contribute to better decision making in determining which repairs, maintenance, and inspections are to be accomplished during a scheduled availability?

Categorical Analysis

Scope

Respondents directly or implicitly indicated that the proposed framework of project-risk and life cycle management of ship inspection, repair, and maintenance will provide solid engineering criteria to enable SURFMEPP to argue on behalf of the ship's need for accomplishment to other commands. This will enable higher echelon commands to review recommendations from a purely engineering perspective that is based solely on a ship reaching its 35-year service life.

Zero Ship Inspection and Work Deferrals

Respondents cited the proposed framework will positively impact the attainment of each ship's 35-year service life. Dependency relationships for the proposed framework based project risk and life cycle management with SURFMEPP Activity being the prime influence towards scheduling ship inspections, repairs, and maintenance for an availability period. The SURFMEPP Activity is the ideal command to influence other organizations in the attainment of a 35-year service life for each ship.

Risk Analytic Method and Engineering Processes

The proposed framework of the project-risk and life cycle management will be a unique perspective (managed by SURFMEPP) in selecting which ship inspections, repair, and maintenance are to be accomplished in a ship's availability period. This perspective will provide other commands the information necessary for the ship to attain its 35-year service life. The organizational challenge will be to effectively communicate to outside organizations the need for scheduled inspections, repairs, and maintenance work items, based solely on life cycle with implications of failure or increased costs.

Summary

As described above, respondents cited key long term challenges to implementing this framework to the current ship repair and maintenance process.

Text Analysis of Respondent Narratives

The following are highlights from the text analysis of the narratives for this question:

Most Frequent Words: yes, advocate, capture, "honest broker," absolutely, & balance.

Phrase Prominence: technically required work, ensure risk and requirements are in balance, advocate for budgets, expected service life, end to end process, determine if technical risk is too high, notify NAVSEA05 and TYCOM for guidance, & better identification of system, equipment, and component risks.

Table 9: Question Analysis Cards
Question 9: What concerns do you foresee in the Navy implementing the proposed framework?

Categorical Analysis

Scope

Respondents directly or implicitly indicated that the proposed framework of project-risk and life cycle management of ship inspection, repair, and maintenance engineering on behalf of the ship's service life by SURFMEPP will meet with resistance from other commands. This structure enables higher level commands to have override authority from their perspective of other reasons.

Organizational and Command Imperatives

Respondents cited the proposed framework could provide positive feedback towards scheduled availability work packages with the secular interest of the ship meeting its 35-year service life. Dependency relationships for the proposed framework based project risk and life cycle management approach, with SURFMEPP being the prime influence towards scheduling ship inspections, repairs, and maintenance for an availability period. The SURFMEPP Activity is the command that can recommend to the TYCOM and NAVSEA regarding the work package with/without deferrals, with the perspective of the ship 35-year service life.

Ship System Reliability, Readiness, Cost Savings, Deployment Ready

The proposed framework of the project-risk and life cycle management is a unique perspective in scheduling ship inspections, repairs, and maintenance items to be accomplished during a ship's availability period. This framework, from a systems engineering management perspective information on project risk management with a life cycle approach that can improve the ship repair and maintenance program, specifically regarding reliability, ship readiness, long term cost reduction, and ships that are in deployment ready status. Readiness will be possible for the duration of its 35-year service life. The organizational challenge will be for SURFMEPP to effectively communicate to TYCOM and NAVSEA the imperative to require periodic inspections, repairs, and maintenance work to be accomplished, based on the life cycle to minimize system and HM&E failures.

Summary

As described above, respondents cited key long term challenges to implementing this framework to the current ship repair and maintenance process.

Text Analysis of Respondent Narratives

The following are highlights from the text analysis of the narratives for this question:

Most Frequent Words: decision-maker, honest-broker, stability, obligation, funding, impediments, goals, & implementation.

Phrase Prominence: uniting TYCOM and NAVSEA, TYCOM responsibility, technically-warranted engineers, ensure safe operation, long term employment of warships, maintaining requisite shore based resources, execute maintenance, technical warrant holder, technical risk, decision authority for operational risk, not enough funding, political winds, budgetary processes, changing leadership and management views, long term vision of fleet inspection, repair and maintenance, & goals may preclude its acceptance and implementation.

This table provides several analysis processes for each question and uses the *most frequent word* and *phrase prominence* categories citing highlights from each respondent's narrative relating to the proposed framework. A categorical analyzes further explains specifics towards each question relating to the proposed framework. Each card contains a summary of the respondent's impression of the question posed towards the proposed framework.

Table 10: Rated Industry Assessment Analysis by Question

Four subject matter experts from different organizations within the Navy's ship repair and maintenance command structure were used in the expert-opinion elicitation process. In assembling and analyzing survey replies and the follow up interviews, the individual responses are identified in this table. The table summarizes and identifies each respondent's response as either comments or phrases, and tallies each respondent's concurrence or disparity, related to the proposed project-risk management and life cycle framework The results of the survey and interview data were analyzed from each respondent and noted in this table as positive (+1) or negative (-1). The data was assessed in aggregate form per question and evaluated as comments indicate:

Question 1	Respondents			
What will be the short term impact on the ship availability process?	#1	#2	#3	#4
a. increased multi-year budgets	-1		-1	-1
b. improved work package	1		1	1
c. robust process for risk of deferral	1			1
d. current readiness may be lessened		1		
e. more time for maintenance needed		1		1
f. better integrated budget projections			1	
g. technically developed multi-year budget			1	
h. CMAV assessments will increase				1

- Three of the four respondents indicated the framework would necessitate "increased of multi-year budgets" to execute the back log of deferred inspections, repairs, and maintenance items on each ship's Consolidated Ship Maintenance Project (CSMP).
- Three out of four respondents indicate the implementation of the proposed framework would provide "improved work package" from each ship's CSMP.
- Two out of four respondents indicated the proposed framework would provide a "robust process for risk of deferral" and would thereby improve availability work packages.
- Two out of four respondents indicated that "more time for maintenance is needed" to catch up on the previously deferred inspections and work.
- One respondent voiced concerns that "current readiness may be lessened" due to the increased maintenance time needed to complete deferred inspections, repairs and maintenance work items.
- One respondent indicated the framework would provide for "better integrated budget projections."
- One respondent indicated the framework would provide a "technically developed multi-year budget" which would be more explicative for obtaining increases in SR&M funding.
- One respondent indicated the framework would provide the needed argument for increased "continuous maintenance availability (CMAV)" periods in ship schedules.

Question 2	Respondents			
What will be the long term impact on the ship availability process?	**#1**	**#2**	**#3**	**#4**
a. improve end-to-end maintenance process	1			
b. identify well defined requirements	1	1	1	
c. assist to achieve expected service level	1			
d. would stabilize SR&M process		1	1	
e. make planning maintenance process repeatable		1	1	
f. make well defined requirements for ESL (expected service life)		1	1	
g. improve technical review and validation			1	
h. increase in maintenance periods				-1
i. require more man-hours				-1

- Three out of four respondents indicated that the framework would improve the current SR&M program by “identifying well defined requirements” for inclusion into the ship’s availability work package, thus improving the long term availability process.
- Two out of four respondents indicated that the framework “would stabilize the SR&M process” with the inclusion of all inspections, repairs and maintenance work items for the long term availability process. .
- Two out of four respondents indicated the proposed framework would “make the planning maintenance process repeatable,” for the long term availability process.
- Two out of four respondents indicated the proposed framework would “make well defined requirements for each ship’s expected service life (ESL)” for the long term availability process.
- One respondent indicated the framework would “improve the end-to-end maintenance process” over the long term availability process.

- One respondent indicated the framework would "assist to achieve expected service level" for each ship's availability over the long term.
- One respondent indicated the framework would "improve technical review and validation" over the long term availability process.
- One respondent indicated the framework would "increase maintenance periods" over the long term availability process.
- One respondent indicated the framework would "require more man-hours" to accomplish the deferred work in the long term.

Question 3	**Respondents**			
What will be the scheduling impact on facilities and/or workforce for availabilities?	**#1**	**#2**	**#3**	**#4**
a. more depot level maintenance work	**-1**		**-1**	**-1**
b. seamless scheduling with processes	**1**		**1**	**1**
c. increased volume of private sector work	**-1**	**-1**		**-1**
d. identifying right duration of shipyard periods	**1**	**1**		**1**
e. cycle analysis improvement	**1**		**1**	**1**
f. standardized processes		**1**		
g. long term savings in SR&M		**1**		**1**
h. SR&M process efficiencies	**1**		**1**	
i. increased funding for SR&M			**1**	
j. increased ship service life				**1**
k. reduce risk (ship systems)				**1**

- Three out of four respondents indicated that the framework would cause "more depot level maintenance work" to be performed.
- Three out of four respondents indicated that the framework would cause facilities a more "seamless scheduling with processes" in coordinating manpower and facilities during availabilities.

- Three out of four respondents indicated that the framework would create an “increased volume of private sector work.”
- Three out of four respondents indicated that the framework would require “identifying right duration of ship yard periods.”
- Three out of four respondents indicated that the framework would make determining “cycle analysis improvement” easier to determine.
- Two out of four respondents indicated the proposed framework would set up “long term savings in the ship repair and maintenance” program.
- Two out of four respondents indicated the proposed framework would result in “ship repair and maintenance process efficiencies” due to the life cycle application to deferral risks.
- One respondent indicated the framework would “standardize processes” within the Navy’s ship repair and maintenance program.
- One respondent indicated the framework would require “increased funding for ship repair and maintenance” budgets.
- One respondent indicated the framework would have an impact on “increased ships service life” towards the 35-year goal.
- One respondent indicated the framework would “reduce risk (ship systems)” by performing work items during availabilities.

Question 4	**Respondents**			
What will be the scheduling impact on ship deployments?	**#1**	**#2**	**#3**	**#4**
a. support ship operations	**1**		**1**	**1**
b. no deployment impact	**1**		**1**	**1**
c. balanced maintenance approach	**1**		**1**	
d. balance readiness with future service life	**1**			
e. stabilizing availability planning and execution		**1**	**1**	
f. reduce churn on the maintenance phase		**1**		
g. better planning and execution of allotted time		**1**	**1**	

- Three out of four respondents indicated that the framework would directly "support ship operations."
- Three out of four respondents indicated that the framework would have "no deployment impact" as ship repair and maintenance schedules are fixed.
- Two out of four respondents indicated the proposed framework would enable a "balanced maintenance approach" to be executed within the schedule.
- Two out of four respondents indicated the proposed framework would "stabilize availability planning and execution" for ship availabilities.
- Two out of four respondents indicated the proposed framework would require "better planning and execution of allotted time" for availabilities.
- Three out of four respondents indicated that the framework would "balance readiness with future service life" of ships reaching 35-years.
- One respondent indicated the framework would "reduce churn on the maintenance phase." Churn is having partial repair/maintenance "fix" done until a permanent repair/maintenance can be performed.

Question 5	Respondents			
What will be the scheduling impact on the Total Ship System Readiness Assessment program?	#1	#2	#3	#4
a. more structured visits in port and underway	1		1	
b. short term availability issues - manpower	-1			
c. put subject matter experts on the ship to assess critical ship systems	1	1	1	
d. formalize requirements for cycle assessments		1		
e. necessary resources to execute TSRA			1	
f. ship input, documentation & control of its consolidated ship maintenance plan (CSMP)			1	
g. reduce downtimes of ship systems, equipment, & components				1
h. reduced time-based maintenance work items				1
i. improve the condition-based maintenance process				1

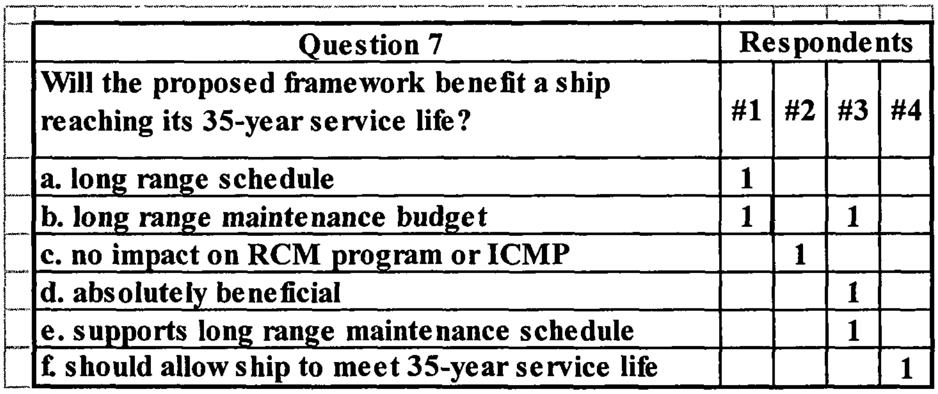
- Three out of four respondents indicated that the framework would assist TSSRA to "put subject matter experts on the ships to assess critical ship systems."
- Two out of four respondents indicated that the framework would foster a "more structured visits in port and underway," supporting TSSRA objectives.
- One out of four respondents indicated that the framework would identify "short term availability issue of manpower" and bring the issue to TSSRA authority.
- One out of four respondents indicated that the framework would "formalize requirements for cycle assessments" of ship systems, equipment, and components supporting the TSSRA program.
- One out of four respondents indicated that the framework would enhance TSSRA in "ship input, documentation and control of its consolidated ship maintenance plan (CSMP) supporting the TSSRA program.

- One out of four respondents indicated that the framework would "reduce downtimes of ship systems, equipment, and components" supporting the TSSRA program.
- One out of four respondents indicated that the framework would "reduce time-based maintenance work item" supporting TSSRA program.
- One out of four respondents indicated that the framework would "improve the condition-based maintenance process" of TSSRA program.

Question 6	**Respondents**			
How will the new framework affect the Reliability-Centered Maintenance (RCM) program?	**#1**	**#2**	**#3**	**#4**
a. no impact on RCM program	**1**			
b. formalize requirements within cycles		**1**		
c. standard assessment execution in support of availability		**1**		
d. will compliment the RCM model			**1**	**1**
e. will positively impact the RCM program				**1**

- Two out of four respondents indicated that the framework "will compliment the RCM model."
- One out of four respondents indicated that the framework would have "no impact on the RCM program."
- One out of four respondents indicated that the framework would "formalize requirements within cycles" fostering the RCM Program.
- One out of four respondents indicated that the framework would provide a "standard assessment execution in support of availability" work items supporting the RCM program.

- One out of four respondents indicated that the framework "will positively impact the RCM program."



Question 7	Respondents			
Will the proposed framework benefit a ship reaching its 35-year service life?	#1	#2	#3	#4
a. long range schedule	1			
b. long range maintenance budget	1		1	
c. no impact on RCM program or ICMP		1		
d. absolutely beneficial			1	
e. supports long range maintenance schedule			1	
f. should allow ship to meet 35-year service life				1

- Two out of four respondents indicated that the framework would enable the planning of a "long range maintenance budget."
- One out of four respondents indicated that the framework would benefit a ship's "long range schedule" for planned availabilities.
- One out of four respondents indicated that the framework would have "no impact on the RCM program or ICMP."
- One out of four respondents indicated that the framework would be "absolutely beneficial" for SR&M program.
- One out of four respondents indicated that the framework "supports long range maintenance schedule" planning towards its 35-year service life.
- One out of four respondents indicated that the framework "should allow ship to meet 35-year service life."

Question 8	**Respondents**			
Will the proposed framework contribute to better decision making in determining which repairs, maintenance, and inspections are to be accomplished during a scheduled availability?	#1	#2	#3	#4
a. yes	1	1	1	1
b. assist scheduling technically required work	1	1		1
c. capture deferred work	1	1		
d. provide honest broker assistance	1			
e. balance risk and requirements	1		1	1
f. advocate for budget		1		
g. expected ship life (ESL) attainable		1		
h. structured end-to-end process		1		

- Four out of four respondents indicated "yes" that the framework would contribute to better decision making for availabilities.
- Three out of four respondents indicated that the framework would "assist scheduling technically required work" for planned availabilities.
- Three out of four respondents indicated that the framework would "balance risk and requirements" for a ship's availability work package.
- Two out of four respondents indicated that the framework would "capture deferred work" for a ship's availability work package.
- One out of four respondents indicated that the framework would "provide honest broker assistance" for determining a ship's availability work package.
- One out of four respondents indicated that the framework would "advocate for budget" for completing ship availability work packages.
- One out of four respondents indicated that the framework would assist a ship to meet its "expected ship life (ESL)" as an "attainable" goal through the ship's availability work packages.

- One out of four respondents indicated that the framework would enable the "structured end-to-end process" for determining a ship's availability work package over its service life.

Question 9	**Respondents**			
What concerns do you foresee in the Navy implementing the proposed framework?	**#1**	**#2**	**#3**	**#4**
a. SURFMEPP not decision maker	**-1**			
b. need tech warranted engineers	**-1**	**-1**		
c. ensure safe operation & long term employment	**1**			
d. stability in SR&M funding		**1**		
e. availability of shore based resources		**1**		
f. TYCOM is the risk decision maker		**-1**		
g. not enough funding for SR&M			**-1**	
h. political winds & budgetary processes				**-1**
i. changing leadership and goals				**-1**
j. vision changes of fleet maintenance and inspections				**-1**
k. goals may preclude its acceptance and implementation				**-1**

- Two out of four respondents indicated that the framework requires that there is a "need for technically warranted engineers" to meet the inspection schedule of deferred work.
- One out of four respondents indicated that the framework provides that SURFMEPP be the command to make the final decision, but "SURFMEPP is not the decision maker."
- One out of four respondents indicated that the framework would "ensure safe operation and long term employment" requiring trained personnel on the ships

and at repair and maintenance facilities, commands, organizations, both government and commercial.

- One out of four respondents indicated that the framework would provide "stability in SR&M funding" of ship inspections, repairs and maintenance programs.
- One out of four respondents indicated that the framework would be challenged with the "availability of shore based repair and maintenance facilities, commands, organizations, both government and commercial.
- One out of four respondents indicated that the framework would not be acceptable because the "TYCOM is the risk decision maker" and that decision process is not negotiable.
- One out of four respondents indicated that the framework would be negatively affected due to "not enough funding for SR&M" work packages.
- One out of four respondents indicated that the framework would be negatively affected due to "political winds and budgetary processes."
- One out of four respondents indicated that the framework would be negatively affected due to "changing leadership and goals."
- One out of four respondents indicated that the framework would be negatively affected due to "vision changes of fleet maintenance and inspections."
- One out of four respondents indicated that the framework would be negatively affected in that "goals may preclude its acceptance and implementation."

Table 11: Survey Response Analysis by Question

Table 11 summarized the results from Table 10 identification of respondent data by phrases, indicating similarities for each question.

		Responses		
Question	**Survey Question**	**Positive**	**Neutral**	**Negative**
1	**What will be the short term impact on the ship availability process?**	25%	56%	19%
2	**What will be the long term impact on the ship availability process?**	36%	61%	3%
3	**What will be the scheduling impact on facilities/workforce for availabilities?**	43%	48%	9%
4	**What will be the scheduling impact on ship deployments?**	50%	50%	0%
5	**What will be the scheduling impact on the Total Ship System Readiness Assessment program?**	31%	66%	3%
6	**How will the new framework affect the Reliability-Centered Maintenance program?**	30%	70%	0%
7	**Will the proposed framework benefit a ship reaching its 35-year service life?**	29%	71%	0%
8	**Will the proposed framework contribute to better decision making in determining which repairs, maintenance, and inspections are to be accomplished during a scheduled availability?**	50%	50%	0%
9	**What concerns do you foresee in the Navy implementing the proposed framework?**	9%	73%	18%

Table 11: Survey Response Analysis by Question.

The information elements originating from the respondents raw data was analyzed by the aggregate process of adding all *positive*, *neutral*, and *negatively* assessed response in relation to the question and the proposed framework. Each category was calculated as a percentage of the total responses by all subject matter experts. Each respondent provided comments, which differed in number and perspective. Each grouped response was divided by the total responses per question.

Table 12: Survey Response Analysis

Table 12 combines the results from Table 11 into an aggregated analysis of the proposed framework.

		Responses		
Survey Question		**Positive**	**Neutral**	**Negative**
Q1	**What will be the short term impact on the ship availability process?**	**25%**	**56%**	**19%**
Q2	**What will be the long term impact on the ship availability process?**	**36%**	**61%**	**3%**
Q3	**What will be the scheduling impact on facilities/workforce for availabilities?**	**43%**	**48%**	**9%**
Q4	**What will be the scheduling impact on ship deployments?**	**50%**	**50%**	**0%**
Q5	**What will be the scheduling impact on the Total Ship System Readiness Assessment program?**	**31%**	**66%**	**3%**
Q6	**How will the new framework affect the Reliability-Centered Maintenance program?**	**30%**	**70%**	**0%**
Q7	**Will the proposed framework benefit a ship reaching its 35-year service life?**	**29%**	**71%**	**0%**
Q8	**Will the proposed framework contribute to better decision making in determining which repairs, maintenance, and inspections are to be accomplished during a scheduled availability?**	**50%**	**50%**	**0%**
Q9	**What concerns do you foresee in the Navy implementing the proposed framework?**	**9%**	**73%**	**18%**

Table 12: Survey Response Analysis.

Each column, positive, neutral, and negative were added and averaged to determine the aggregate percentage of acceptance or potential impact the proposed framework would have on the current SR&M process, organizational impacts, and resources.

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