

**NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA**



THESIS

**AN APPROACH TO USING TOTAL LIFE
CYCLE COST AND TOTAL QUALITY
MANAGEMENT IN PROJECT MANAGEMENT
IN THE INDONESIAN NAVY**

by

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September, 1996

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**AN APPROACH TO USING TOTAL LIFE CYCLE COST AND TOTAL
QUALITY MANAGEMENT IN PROJECT MANAGEMENT IN THE
INDONESIAN NAVY**

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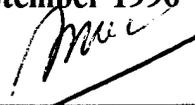
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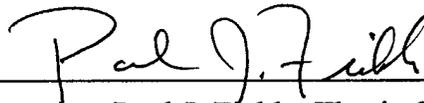
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ABSTRACT

Project management is very important to many industrial and governmental organizations. For governmental organizations, projects are vehicles for growth and improvement. In the Indonesian Navy for example, project management is needed to develop new warships, such as destroyers or submarines. The goal of project management is to make a high quality result.

Generally speaking, quality is defined as adherence to specifications and high quality is defined as exceeding those specifications. Not meeting the specifications is unacceptable quality. For a project like building a warship, the Total Life Cycle Cost can be considered primarily as a function of four things: design, construction, operation and maintenance. The selection of the design and the contractor are one time decisions and cannot be changed over the life of the ship. In contrast, operation and maintenance are on-going management decisions, yet they are largely determined by the design selected and the quality of the contractor's work.

To have the lowest Total Life Cycle Cost, the right design and the right contractor must be selected. This thesis develops a Design Review Checklist and a Contractor Review Checklist that can be used in reviewing the contractor's design and the contractor's quality management capabilities.

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I. INTRODUCTION

A. PROJECT MANAGEMENT

Project management is very important to many industrial and governmental organizations. For industrial organizations, projects are the means by which new products are designed, developed and brought to market. For governmental organizations, projects are vehicles for growth and improvement. As an agent of change, the government must take the lead in requiring quality, starting from project inception through the maintenance requirements of each system. Other institutional forms of organizations, like educational systems, also create and improve their service through programs and projects.

Project management is a method of planning, monitoring and controlling an assigned job to achieve the desired results on schedule and within a specified cost. The Project Manager is the person responsible for project management. He has to identify and manage the project team to integrate the efforts of all contributors to the project. Projects, by definition, consist of many different tasks that demand the skill and assets of a number of a different disciplines. These jobs are assigned to numerous people, both internal and external to the organization. However, the Project Manager retains the primary responsibility for the project. In addition, other persons may hold regulatory, approval, and decision-making authority, over some aspects of the project. Everyone assisting in a given project is considered a member of that project team. The most successful project management is achieved when all members collaborate and work together as a team under the integrative leadership of the project manager.

B. QUALITY

In American business and industry and even in public service and government agencies, the watchword is quality. Producing high quality products not only requires the effective use of resources, but also the minimization of repair, rework, scrap and failure costs by preventing defects before they occur. The cost of preventing defects is normally much less than the cost of failures, rework and corrective action.

Quality is defined broadly as adherence to specifications, and high quality is defined as exceeding those specifications. Not meeting specifications is unacceptable quality. The objective in project management is to minimize the variability around those specifications to have low Total Life Cycle Cost (TLCC).

C. TOTAL LIFE CYCLE COST

For a ship, Total Life Cycle Cost can be considered a function of four things: design, construction, operation and maintenance. Design and contractor selection are one time decisions, and can not be changed over the life of the ship. In contrast, operation and maintenance are on-going management decisions. Selecting the right design and the right contractor should make the operation and maintenance costs lower.

This research focuses on the one time design and contractor selection decision. A quality product is one which meets the customer's desired performance criteria with the lowest TLCC. To achieve this, quality engineering in design and quality management in construction are necessary. The prime objective of project management is the prevention of failure in the future, because the decisions made during the design and construction stages can have a serious impact on the life cycle cost for a system.

D. TOTAL QUALITY MANAGEMENT

The purpose of this thesis is to determine how to review the design and how to review the contractor to ensure a minimum Total Life Cycle Cost. By definition, Total Quality Management (TQM) means that the organization's culture supports the achievement of customer satisfaction through an integrated system of tools, techniques and training. This involves the continuous improvement of organizational processes resulting in high quality products. A fundamental tenet of TQM is to choose a contractor based upon quality, not solely upon price. Unlike a repetitive manufacturing process where sampling can be used to assess the quality of the producer, a project is a one-time event. Therefore, sampling cannot be used to evaluate the performance of a contractor. The challenge is to evaluate the quality of the contractor before he performs the job. It is important to note, however, that even a good contractor cannot compensate for a poor or

inappropriate design. Therefore, another challenge is to evaluate the appropriateness of the design before selecting the contractor.

The engineering and management decisions made in the early phases of the system life cycle have a great impact on sustaining operation and maintenance support. Operation and maintenance support activities often constitute a large percentage of the total cost of a system. It is important to expand the decision-making process to address system requirements from a total life cycle perspective. The application of life cycle cost analysis methods can facilitate this objective.

People often find a lack of total cost visibility when considering the costs over the entire life cycle of a system. The total cost visibility problem can be related to the “iceberg effect” illustrated in Figure 1.

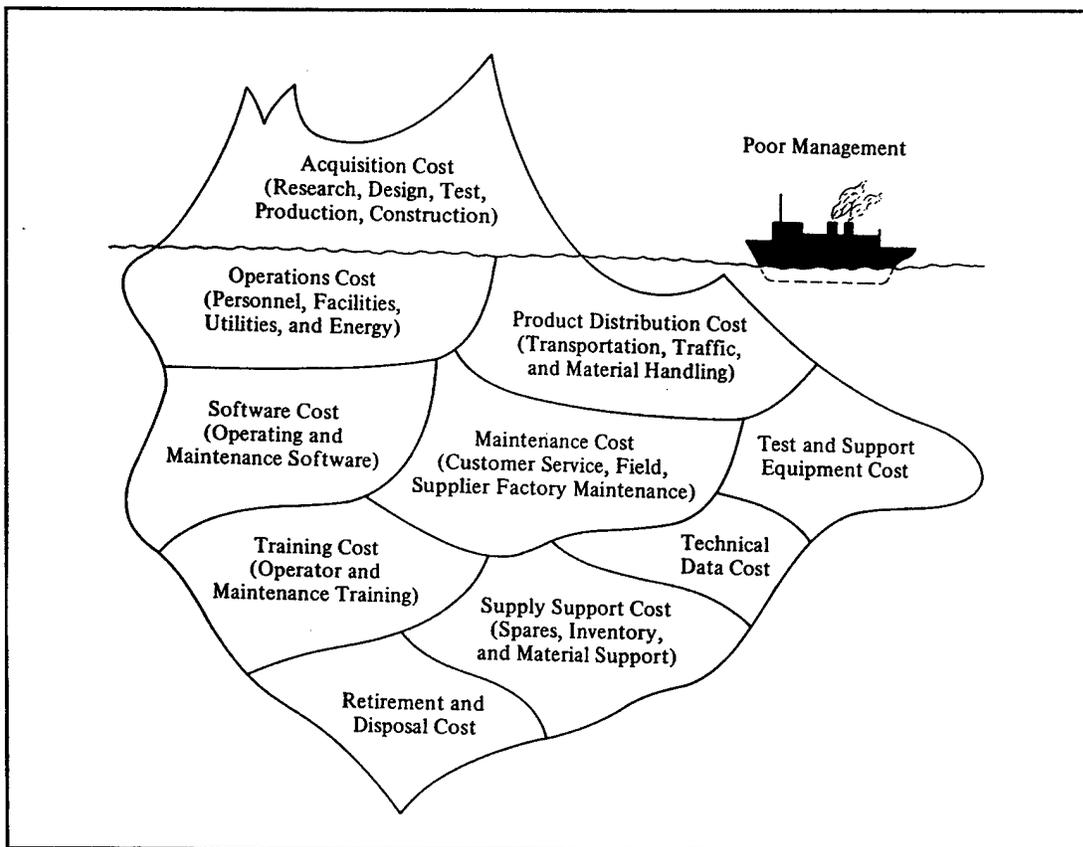


Figure 1. Total Cost Visibility [Ref 2: p.71]

The acquisition costs associated with research, design, testing, production, initial procurement and installation of new equipment are often highly visible and usually decisions are made based solely on these costs. However, the costs associated with the utilization, maintenance and support of the system throughout its whole life cycle can be somewhat hidden. It is essential to address total cost visibility in a new project, so that not only the visible system acquisition costs, but also all other costs are taken into consideration for making decisions.

The process of awarding the contract for a project is illustrated in Figure 2. Based upon threat analysis and the military capability desired by the government, there is a “need” to build a warship. The government’s need is translated via requirement analysis into operational requirements. The government issues the list of operational requirements, makes a Request For Proposal (RFP), and invites contractors A, B, and C to respond. The contractors submit detailed proposals for a ship answering those requirements. After receiving the proposals, the government conducts a system design review and contractor review which will analyze them from the point of view of mission performance, cost, and risk. This thesis addresses the problem of how the government can evaluate competing proposals to select not only the best design, but also the best contractor.

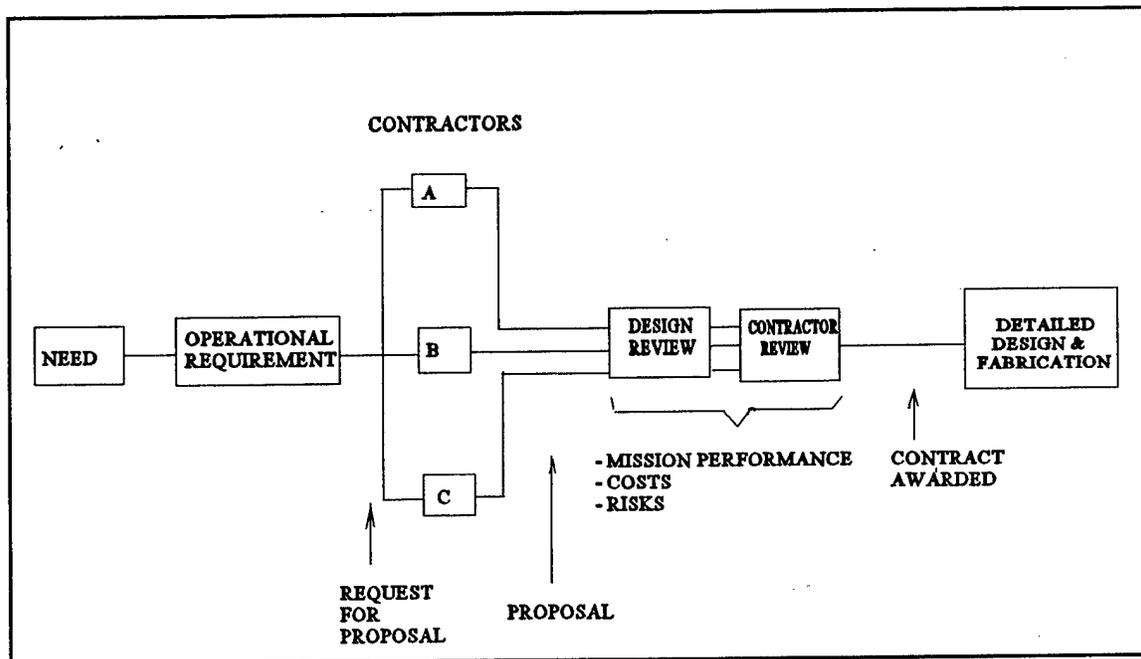


Figure 2. Project Contract Awarding Process

E. REQUEST FOR PROPOSAL

To ensure success in the proposal process, it is important for the government to define precisely its needs and the criteria it will use for the design and contractor evaluations. The statement of the government's needs must be addressed clearly in the RFP. This facilitates the contractors' proposal preparation and makes the evaluation process much easier for the government, if all of the contractors have answered the same questions. For example the RFP should discuss:

1. Mission Performance

Mission Performance is a definitive statement of what the ship combat system is expected to do, the nature of the anticipated threats it will encounter, and the operational situations in which it will have to perform.

2. Sea Worthiness

Sea worthiness is a description of the ship's expected capability for endurance, speed, sea state, fuel consumption, logistics, etc.

3. Ship Performance

Ship Performance is a description of the ship's propulsion, energy generation, navigation and communication, sensor and weapon systems, as well as the required personnel and their training.

4. Operational Environment

Operational Environment is a description of the ship's expected environment of operation including electromagnetic, noise, shock and internal vibration, ambient and sea temperatures, humidity, and maintenance facility environments.

5. Equipment List

The Equipment List is a description of the standard equipment to be included on the ship.

6. System Engineering Management Plan (SEMP)

The SEMP describes the development of the prime planning document dictating program management activities that will help to ensure a well-coordinated and integrated product output.

7. Test and Evaluation Master Plan (TEMP)

The TEMP describes an integrated test plan designed to verify whether system requirements have been achieved.

8. Measures Of Effectiveness (MOE)

The MOE describes how system effectiveness and cost effectiveness will be evaluated relative to the ship's availability, dependability, capability, readiness, life-cycle cost, etc.

9. Logistic Support Analysis (LSA)

The LSA describes the logistic support resource requirements that the government needs to provide after the system has been built.

10. Level Of Repair Analysis (LORA)

The LORA describes the expected level of repair for all equipment to maintain the system during its useful life.

F. RESEARCH PURPOSE

The purpose of this thesis is to determine appropriate ways to evaluate the engineering design and the contractor before the project begins to ensure a balance between maximum capability and minimum TLCC. The remainder of this thesis is divided into four chapters: Chapter II discusses the design review; Chapter III focuses on the contractor review; Chapter IV addresses the application of TLCC and TQM to shipbuilding in the Indonesian Navy; and Chapter V presents conclusions and recommendations.

II. DESIGN REVIEW

A. DESIGN QUALITY

A quality product is the product which meets the user's desired performance criteria with the lowest TLCC. The desired performance criteria for a warship are the characteristics that the government wants in the ship. These can include mission capability, sea worthiness, survivability, maintenance, etc.

To ensure that the product will be a quality product, the government needs to carefully evaluate the contractor's proposed design. The prime objective of evaluating the appropriateness of the design is the prevention of failure in the future, because the decisions made during the design and construction stages have a serious impact on the performance and Total Life Cycle Cost of the ship.

The government should try to find all potential flaws in the design because it will be far less costly to fix them before the ship is built rather than after it is in operation.

B. DESIGN REVIEW

Design review is one of the essential evaluations conducted by the government in order to select the best design. To perform the design review, the government must establish a Quality Survey Team made up of three Naval Officers whose ranks are between Lieutenant Commander and Colonel. They should be specialists who each have at least 11 years of professional experience. One of the the three should have a degree in Naval Engineering with specialization in Structural design, the second officer's degree should be in Mechanical Engineering with specialization in Propulsion and Auxiliaries Systems, and the third officer's degree should be in Electrical Engineering with specialization in Power, Sensor, and Weapons Systems.

A design review can be conducted by answering the questions in the checklist presented in this section. It has been developed to verify if the contractor's proposed design meets the government's requirements. The answer to the questions should be "YES" in order to expect desirable results. The questions are representative of what

should be considered in conducting a design review in building a warship. Although all the questions are applicable to the design of a warship, they are not all applicable to all types of warships. When a question does not apply to the type of warship being reviewed, that question can be disregarded. The checklist is adapted from Blanchard [Ref. 3] and Plich and Rager [Ref. 16].

C. CHECKLIST

1. Operational Requirements

1.1 Mission Performance and Military Capability

- 1.1.1 Has the technical design approach from the ship's mission performance been justified through different scenarios, including primary and secondary missions as contained in the RFP?
- 1.1.2 Has the design considered critical performance parameters such as probability of kill, probability of survival, and probability of detection?
 - 1.1.2.1 How are the performance parameters measured?
 - 1.1.2.2 Are the performance parameter measurements valid?
- 1.1.3 Have government scenarios and requirements such as endurance, speed, and logistics been evaluated?
- 1.1.4 Are the combat system detection and engagement elements defined in the design including sensor and detection system, and weapons system?
- 1.1.5 Have existing technologies been selected where feasible, as compared to the selection of new state-of-the-art technologies?
- 1.1.6 In the evaluation of alternative technology applications, have life-cycle cost considerations been employed and have peculiar support requirements been identified?
- 1.1.7 Will the technologies selected be available in time to satisfy program schedule requirements?
- 1.1.8 Are there multiple sources of supply or more than one subcontractor for each of the technologies selected for implementation?

1.1.9 Have research and development activities been defined for areas where deficiencies exist?

1.1.10 Have areas of risk and uncertainty been identified?

1.1.11 Have trade-off studies between mission performance and cost been employed?

1.2 Sea Worthiness

1.2.1 Has the sea worthiness requirements such as sea state, endurance, speed, and fuel consumption in the RFP been met and how can this be verified?

1.2.2 Have individual ship performance requirements been evaluated such as propulsion, sensor and weapon systems, and habitability?

1.2.3 Has the operational life cycle of the ship been adequately determined considering design development, production or construction, operational use, logistics, maintenance, and disposal?

1.2.4 Has the contractor stated how he will meet the operational environment requirements concerning ambient temperature, humidity, shock, vibration, and electromagnetic environment?

1.3 Maintenance

1.3.1 Have the anticipated levels of maintenance been identified and defined?

1.3.2 Have the basic maintenance functions been identified for each level?

1.3.3 Have the organizational responsibilities for system maintenance and support been identified including ship support, contractor support, intermediate support, and depot support?

1.3.4 Have level-of-repair policies such as repair versus discard been established and have the criteria for level-of-repair decisions been adequately defined?

1.3.5 Have criteria been established for test and support equipment at each level of maintenance including built-in versus external test equipment and diagnostic requirements?

- 1.3.6 Have software requirements for system and component testing been defined as well as the test language requirements?
- 1.3.7 Have the following been addressed in the contractor's life cycle support concept: spare part demand rates, inventory locations and levels, test equipment availability and utilization, maintenance shop line and process time, facility utilization, and turnaround time?
- 1.3.8 Is there a warranty from the contractor that every part for maintenance will not go out of production during the life of the system?
- 1.3.9 Is the detailed maintenance analysis compatible with system performance, reliability, supportability data, effectiveness factors and Logistic Support Analysis (LSA) data?
- 1.3.10 Is the system maintainable in terms of relative ease in troubleshooting and diagnostics, accessibility, replacement, handling capacities, accuracy of test and verification, and economics in the performance of corrective and preventive maintenance?
- 1.3.11 Does the contractor's plan include a system corrective and preventive maintenance analysis based on a detailed maintenance engineering analysis including trade-off studies to achieve the correct balance between corrective and preventive maintenance?
- 1.3.12 Does the proposal include plans to conduct a Level Of Repair Analysis (LORA)?

1.4 Effectiveness Factors

- 1.4.1 Have the appropriate system and cost Measures Of Effectiveness (MOE) been evaluated for the system including reliability, maintainability, supportability, availability, dependability, capability, readiness, life-cycle cost, and human factors?
- 1.4.2 Does the proposal adequately address the specified MOE?
- 1.4.3 Is the contractor's Test and Evaluation Master Plan (TEMP) adequate for the purposes of effectiveness verification?

1.5 Functional Analysis and Allocation

- 1.5.1 Has the system been sufficiently defined in functional terms utilizing the functional block diagram approach?
- 1.5.2 Have all major system operational functions and maintenance functions been defined?
- 1.5.3 Are the functions directly trackable to top system-level requirements including the mission scenario?
- 1.5.4 Is the functional analysis introduced in sufficient detail to allow for the proper development of the reliability block diagram, maintainability prediction, maintenance analysis, detailed operator task analysis, operational sequence diagrams, safety hazard analysis, survivability analysis and the Logistic Support Analysis (LSA)?
- 1.5.5 Is the functional analysis introduced in sufficient detail for the development a system specification?
- 1.5.6 Have the correct system-level requirements been allocated to the depth needed for sufficient design definition such as the combat system definition including the allocation of maintainability requirements, reliability requirements, supportability factors and cost parameters?

1.6 System Specification

- 1.6.1 Has a system specification been prepared?
 - 1.6.1.1 Does the system specification address all of the items identified in Appendix A?
 - 1.6.1.2 Does the system specification contain functional and performance requirements such as missions, threat, required states and modes, capability, reliability, maintainability, deployability, availability, and computer resource requirements?
- 1.6.2 Does the system specification address maintenance ?
- 1.6.3 Has a factory-to-disposal profile been prepared?

1.7 Subcontractor Plans

- 1.7.1 Have the procedures and criteria for the initial identification, evaluation, and selection of component subcontractor been accomplished?
- 1.7.2 Have all major component subcontractors been identified?

1.8 System Engineering Management Plan (SEMP)

- 1.8.1 Has the contractor developed a System Engineering Management Plan (SEMP)?
- 1.8.2 Does the SEMP meet all the requirements of Appendix B?
 - 1.8.2.1 Does the plan sufficiently describe the system engineering process to be followed?
 - 1.8.2.2 Is there a procedure to ensure currentness, completeness and the engineering sufficiency of drawings?
 - 1.8.2.3 Do the contractor and subcontractor program plans describe in detail the technical effort?
 - 1.8.2.4 Does the program clearly describe and cover the contractor's responsibility for controlling and recording design and other changes originating with subcontractors?
 - 1.8.2.5 Does the contractor monitor all subcontractor changes which demand his approval?
 - 1.8.2.6 Does the SEMP correctly describe Requirement Analysis, Functional Analysis/Allocation, Synthesis, System Analysis and Control ? Have major system trade-off studies been sufficiently documented, and are they correctly referenced in the SEMP?
 - 1.8.2.7 Does the plan carry the correct integration of the different engineering specialties concerned in the system design process?
- 1.8.3 Does the SEMP address the overall system life cycle and its phases/activities?
- 1.8.4 Is the SEMP compatible with the TEMP and the Acquisition Strategy Plan (ASP)?

- 1.8.5 Is there suitable monitoring by the contractor of all changes not requiring government approval?
- 1.8.6 Does the program clearly describe and cover the contractor's procedures for controlling and recording design and other changes originating with subcontractors?
- 1.8.7 Has a quality program been included in the contractor's proposal?
- 1.8.8 Has a Total Quality Management plan been prepared and implemented and does it include user, contractor, and subcontractor activities as well as interfaces?
- 1.8.9 Is quality achieved by effective control of all work during the manufacturing processes?
- 1.8.10 Are formal quality training programs being conducted within the user/contractor/subcontractor organization?
- 1.8.11 Are Statistical Process Control (SPC) methods/techniques planned where applicable?
- 1.8.12 Are quality control requirements specified and enforced on all subcontractors?

2. Design Features

2.1 Ship Structure and Layout

- 2.1.1 Is the ship structure and layout appropriate to support operational requirements and different scenarios contained in the RFP?
- 2.1.2 Has the general arrangement of the ship been adequately defined?

2.2 Survivability

2.2.1 General

- 2.2.1.1 Has survivability been involved as part of cost performance trade off parameters?
- 2.2.1.2 Have cost analyses been conducted to identify design alternatives?
- 2.2.1.3 Have all possibilities been studied to maintain basic capabilities available during combat and to quickly recover basic capabilities that are lost during combat?

2.2.2 Integration of Ship Systems

2.2.2.1 Do the combat system and machinery system redundancies complement each other?

2.2.2.2 Have provisions been made for reconfiguration of the combat system and machinery to recover from casualties?

2.2.3 Survivability Enhancement by Location and Hardening

2.2.3.1 Have sections of the combat system been located in different fire zones and are the sections capable of independent operation in each fire zone?

2.2.3.2 Are important equipment located in such a way to maximize protection provided by less important equipment and by the ship's structure?

2.2.3.3 Have all cables, waveguides, hydraulic lines, cooling lines, etc. been protectively covered from the weather and have weather runs been minimized?

2.2.3.4 Have easily targeted items such as infrared and radio frequency sources been separated away from vital areas?

2.2.3.5 Has the cross sectional area of individual combat system capabilities been minimized?

2.2.3.6 Has an estimate been given as to what happens when major control centers are lost?

2.2.3.7 Have redundant major control centers been considered?

2.2.3.8 Do major control centers only coordinate and not perform an operational function?

2.2.3.9 Have redundant signal paths been isolated as much as possible?

2.2.3.10 Have personnel been considered similar to equipment in regard to protection and location?

2.2.3.11 Does the combat system design maintain separation between commanders during warfare?

2.2.3.12 Is the machinery system designed for flexibility of operation?

2.2.3.13 Is propulsive power distributed redundantly and is there physical separation of vital components?

2.2.3.14 Is electrical power distributed cross-connectably to enhance combat effectiveness?

2.2.4 Survivability Enhancement by Operational Considerations

2.2.4.1 Interchangeability

2.2.4.1.1 Have components of the different combat subsystems been standardized?

2.2.4.1.2 Are equipment, modules, and components that perform similar operations electrically, functionally, and physically interchangeable?

2.2.4.1.3 Can replacements of like items be made without adjustments or alignments?

2.2.4.2 Impacts on Electrical System

2.2.4.2.1 Have ship systems components been designed to minimize fluctuations in the ship's power system?

2.2.4.2.2 Have systems been designed to lose and regain power safely, especially in the middle of a cycle?

2.2.4.2.3 Are systems designed to come back on line as fast as possible after momentary power interruptions?

2.2.4.3 Recovery

2.2.4.3.1 Has speed of recovery from damage in expected hit areas been analyzed?

2.2.4.3.2 Have provisions been made for reconfiguration of all vital ship systems?

2.2.4.3.3 Has a casualty data signal distribution system been installed?

2.2.4.3.4 Is there a total ship integrated data distribution system?

2.2.4.3.5 Have redundant signal paths been provided for vital equipment not located in the same compartment or adjacent compartments?

2.2.4.3.6 Are combat subsystems able to operate independently?

2.2.4.3.7 Is the ship able to operate with reduced performance when systems or parts of systems are lost?

2.2.4.3.8 Is the ship capable of graceful degradation?

2.2.4.4 General Design

2.2.4.4.1 Is there a panel monitoring system for all vital ship systems equipment involved in combat?

2.2.4.4.2 Have requirements been eliminated for special services such as highly regulated voltage, frequency, pressure, or special gas?

2.3 Sensor, Weapons and Control Systems

2.3.1 Has the combat system been defined and justified to support operational requirements through the different scenarios contained in the RFP?

2.3.2 Are their calculations valid?

2.4 Navigation and Communication Equipment

2.4.1 Are the navigation and communication equipment, both internal and external, appropriate to support operational requirements and the different scenarios contained in the RFP?

2.4.2 Does the equipment reflect ease of maneuvering so that it can be handled by a few people?

2.5 Human Factors

2.5.1 What is the contractor's design for automated and manual functions for all the operations that are done on the ship and have they been sufficiently identified?

2.5.2 Are the identified automated/manual functions compatible with the results of the overall system level functional analysis?

- 2.5.3 For human interface functions, is the system design optimum when considering anthropometric factors, human sensory factors, psychological factors, and physiological factors?
 - 2.5.3.1 For manual tasks, does the design reflect "ease of operation" by low skilled personnel?
 - 2.5.3.2 Is the design such that potential human error rates are minimized?
- 2.5.4 Has a detailed training plan for operator and maintenance personnel been prepared and have training facility, equipment, material, software, and data requirements been specified?
- 2.5.5 Is the human factors effort compatible with safety engineering requirements?
- 2.5.6 Does the contractor have acceptable plans for staffing his test and evaluation teams?
 - 2.5.6.1 Are contractor test and evaluation personnel sufficiently qualified for their assignments?

2.6 Computer Systems - Software and Hardware

- 2.6.1 Have all system software requirements for operating and maintenance functions been identified?
- 2.6.2 Are the language requirements for operating software and maintenance software compatible?
- 2.6.3 Are all existing software sufficiently supported through good documentation including logic functional flows and coded programs?
- 2.6.4 Has the existing software been sufficiently tested and verified for accuracy , performance, reliability, and maintainability?
- 2.6.5 Has an acceptable plan for software maintenance been provided?
- 2.6.6 Has software maintenance been included in TLCC calculations?

2.7 Machinery

2.7.1 Propulsion

- 2.7.1.1 Is the propulsion sufficient to support operational requirements in the different scenarios contained in the RFP?
- 2.7.1.2 Do the type of propulsion and ship's auxiliaries selected provide adequate performance?
- 2.7.1.3 What assumption and performance calculations were made to select these item?
- 2.7.1.4 Is the planned fuel consumption reasonable?
- 2.7.1.5 Does the contractor plan for the relative ease of maintenance and operation of propulsion systems?

2.7.2 Energy Generation

- 2.7.2.1 Is the electric power sufficient to support operational requirements in the different scenarios contained in the RFP?
- 2.7.2.2 Does the contractor's plan discuss the impact of generator failure during operation and corrective actions?

2.8 Safety

- 2.8.1 Have system hazards from projected environmental requirements such as sea state, heat, cold, thermal change, barometric change, humidity change, shock vibration, light, mold, bacteria, corrosion, rodents, fungi, odors, chemicals, oils, greases, handling and so on, been identified and minimized?
- 2.8.2 Are the environments such that personnel safety is ensured; specifically, are noise levels within a safe range, is illumination sufficient, is the air clean, and are the temperatures at a proper level?
- 2.8.3 Are safety equipment requirements specified in areas where ordinance devices are activated?

2.8.4 Will equipment safety and protection interlocks be equipped with a battle overload capability?

2.8.5 Have safety device provisions been integrated where possible to provide protection against secondary failures resulting from primary failures?

2.9 Storage

2.9.1 Have adequate storage facilities for food, ammunition, and spare parts been provided?

2.9.2 Can the supply resources be stored for extended periods of time without excessive degradation?

2.10 Accessibility

2.10.1 Are key system components directly accessible for the performance of both operator and maintenance tasks?

2.10.2 Are access doors provided wherever appropriate?

2.10.3 If hinged doors are utilized, can they be supported in the open position?

2.10.4 Are ship's access openings sufficient?

2.10.5 Are access door fasteners minimized?

2.10.6 Are access door fasteners of the quick-release variety?

2.10.7 Can access be achieved without the use of tools?

2.10.8 If tools are required to gain access, is the number of tools held to a minimum and are they standard quality tools?

2.10.9 Are access provisions between modules and components sufficient?

2.10.10 Are access doors and openings labeled in terms of items that are accessible from within?

2.11 Adjustments and Alignments

2.11.1 Have adjustment and alignment requirements been minimized, if not eliminated?

2.11.2 Can adjustment/alignment be made where required?

2.12 Cables and Connectors

2.12.1 Is there a total ship integrated data distribution system?

2.12.1.1 To what extent will multiplexing or data buses be used instead of multiconductor cables?

2.12.1.2 Has the amount of point-to-point cabling been minimized?

2.12.1.3 Has the cabling layout been analyzed for survivability?

2.12.1.4 Has the cabling layout been analyzed for impact on land based testing?

2.12.2 What are the contractor's plans for fabricating and installing all of the cable on the ship?

2.12.3 Has the overall design of the cabling and connectors been carefully considered?

2.12.3.1 Are cables routed to prevent sharp bends?

2.12.3.2 Are cables routed to prevent pinching?

2.12.3.3 Is cable labeling sufficient?

2.12.3.4 Is cable clamping sufficient?

2.12.3.5 Are quick-disconnect connectors used?

2.12.3.6 Are connectors mounted on surfaces far enough apart so that they can be firmly grasped for connecting and disconnecting?

2.12.3.7 Are connectors and receptacles labeled?

2.12.3.8 Are connectors and receptacles keyed?

2.12.3.9 Are connectors standardized?

2.12.3.10 Do the connectors incorporate provisions for moisture prevention?

2.12.3.11 Are the cables shielded where necessary?

2.12.3.12 Has the use of data buses been considered where applicable?

2.13 Calibration

2.13.1 Has the contractor addressed the need for calibration of equipment?

2.13.2 How will calibration be maintained for all equipment?

2.14 Ecological Requirements

2.14.1 Have provisions been made to control at suitable levels noise, temperature, humidity, and illumination in areas where personnel are required to perform operating and maintenance tasks?

2.14.2 Does operation of the ship violate any environmental regulations?

2.15 Base Facility Requirements

2.15.1 Have operational and maintenance facility requirements been minimized to the greatest extent possible?

2.15.2 Have operational facility requirements such as pier space, shore electricity and water supply essential for planned operational deployment been specified?

2.15.3 Have maintenance facility requirements essential for system maintenance at each level such as dock space, capacity, capital equipment, utilities, etc. been specified?

2.15.4 Have environmental system requirements such as temperature, humidity, and dust control associated with operational and maintenance facilities been specified?

2.15.5 Have storage or shelf space requirements for spare and repair parts been specified?

2.15.6 Have storage environments been specified?

2.15.7 Are the designated facility and storage requirements compatible with the logistic support analysis and maintenance concept?

2.16 Handling

2.16.1 Have sufficient provisions been specified for handling and movement of all heavy items which will come on or off the ship?

2.16.2 Can the equipment be easily transported and moved from one location to another?

2.16.3 Can all system components be moved utilizing common and standard handling equipment so that special handling equipment is not needed?

2.17 Habitability

2.17.1 Has enough space been provided for a crew member to live on the ship?

2.17.2 Has thought been given to simplifying the daily maintenance requirements for cleaning the berthing area and bathroom?

2.17.3 To facilitate easier cleaning, could consideration be given to a curved intersection where the floors meet the bulkheads as opposed to a conventional 90 degree angle intersection?

2.17.4 Have food preparation and serving areas been designed to simplify operations and cleanliness and reduce personnel working hours?

2.18 Operability

2.18.1 Is the system designed for relative ease of operation?

2.18.2 Can the system be operated effectively by personnel with basic skills and with a minimum of special training?

2.18.3 Can system operation be achieved with a minimum of error?

2.19 Modularization

2.19.1 Has modularization been considered to the maximum extent possible?

2.19.2 Has modularization been used to facilitate quick and easy repair?

2.19.3 Have interaction effects between modules been minimized?

2.19.4 Is it possible to limit maintenance's work to the removal of one module that contains the failed part when a failure occurs and not require removal of another module in order to resolve the problem?

2.19.5 Is the modularization design compatible with LORA decisions?

2.20 Panel Displays and Controls

2.20.1 Have the panel displays and controls been designed appropriately based on good human factors criteria?

2.20.2 What do they display and do they conform with the control requirements?

2.21 Personnel and Training

2.21.1 Have operational and maintenance personnel quantity and skill level requirements been specified?

2.21.2 Are operational and maintenance personnel requirements minimized to the greatest extent possible?

2.21.3 Are operational and maintenance personnel requirements compatible with the LSA and with human factors criteria?

2.21.4 Are the planned personnel skill levels at each location compatible with the complexity of the operational and maintenance tasks identified?

2.21.5 Has maximum consideration been applied to the use of existing personnel skills for new equipment?

2.21.6 Have operational and maintenance training requirements been specified including both initial training and replenishment training throughout the life cycle?

2.21.7 Have specific training program been planned?

2.21.8 Are the planned training programs compatible with the personnel skill level requirements specified for the performance of operational and maintenance tasks?

2.21.9 Have training equipment requirements been specified?

2.21.10 Have maintenance provisions for training equipment been addressed?

2.21.11 Have training data requirements been specified?

2.22 Producibility

2.22.1 Does the design lend itself to economic production and can simplified fabrication and assembly techniques be used?

2.22.2 Can currently available facilities, standard tools, and existing personnel be employed for fabrication, assembly, manufacturing and test operations?

2.23 Reconfigurability

2.23.1 Does the system configuration show that it can be easily upgraded for improved capability?

2.23.2 Have preplanned product improvements been figured in the initial design of the system?

2.24 Reliability

2.24.1 Is the system simple and have the amount of component parts been kept to a minimum?

2.24.2 Have the shelf life and wear out characteristics of equipments been specified?

2.24.3 Have critical components been identified which need special procurement methods, testing, and handling provisions?

2.24.4 Has the risk associated with critical item failures been specified and accepted?

2.24.5 Have reliability predictions been done?

2.24.6 Have reliability testing requirements been specified?

2.25 Selection of Parts/Materials

2.25.1 Have appropriate standards been considered for ship construction?

2.25.2 Have all component parts and materials selected for the design been evaluated considering performance parameters, quality, and costs?

2.26 Aesthetics and Standardization

2.26.1 Is the overall design attractive from the standpoint of user appeal regarding shape, size, etc?

2.26.2 Has an equipment standardization policy been established for the design?

2.27 Servicing and Lubrication

2.27.1 Does the design philosophy address servicing and lubrication?

2.27.2 Have servicing and lubrication requirements been held to a minimum?

2.28 Societal Requirements

2.28.1 Does the system satisfy religious requirements?

2.28.2 What provisions are made for personnel off-duty activities?

2.29 Supportability

2.29.1 Are the identified logistic pipeline times compatible with efficient supply support?

2.29.2 Have the risk or consequences of stock out been defined in terms of effect on mission requirements and cost?

2.29.3 Has a provisioning or procurement cycle specifying order quantity and frequency been determined considering Economic Order Quantity factors?

2.29.4 Has a supply availability requirement been established noting the probability of having a spare available when required?

2.29.5 Is the test and support equipment selection process based on cost effectiveness considerations over the entire life cycle?

2.29.6 Have test and maintenance software requirements been sufficiently defined?

2.30 Testability

2.30.1 Is there a design philosophy regarding system and element testing?

2.30.2 Have self-test provisions been implemented where appropriate?

2.31 Disposability and Demilitarization

2.31.1 Has the system been designed for disposability after end of service life?

2.31.2 Has disposal been considered in the system concept?

2.31.3 Are the proposed disposal methods compatible with environmental, ecological, political, and social requirements?

III. CONTRACTOR REVIEW

A. QUALITY MANAGEMENT

In building a sophisticated item like a warship, evaluating a contractor's capability is more meaningful than evaluating the acquisition price. This is because of the complexity of the project. A cheap acquisition price for a warship that does not effectively perform is not a bargain. Consequently, in project management the order-winning criteria should be the contractor's capability, not acquisition price. The key factor to consider in evaluating the contractor's capability is to evaluate his quality management program.

What is quality management? Quality management is the capability to not only detect defects and take corrective action after the product has been built, but also to control all work operations during the manufacturing processes. It controls the products in the design phase, the quality of raw materials used, and the capability of the work force, work tools and work processes.

B. CONTRACTOR REVIEW

In full and open competition, each contractor who desires to compete submits a proposal. For a complex military hardware system, like missiles, aircraft, ships, and tanks, Mil-Q-9858A mandates contractors to set up a quality program inherent in their proposal. The evaluation of each contractor is initiated based on the proposals. Initially, the evaluation is for conformity of the contractor's system design description to the government's requirements. However, evaluating the proposal and selecting the best proposal is not adequate. The government needs to not only choose the contractor who can present the best proposal and quality program on paper, it must choose the contractor who has the quality management capability to make the proposal become a reality.

The government can determine if the contractor has quality management by conducting contractor evaluations in the pre-award survey. Each proposal can be evaluated from the following point of view: (1) Quality, (2) Pricing and Financial considerations, (3) Performance, and (4) Inspection Capabilities. Evaluation of quality,

pricing and financial considerations, performance, and inspection capabilities will of necessity be based on prior contracts. What a contractor has done in previous jobs is the best indicator of what he will do on the next job. An in-plant evaluation can be done by a Quality Survey Team which consists of four Naval Officers who are specialists in Naval Engineering, Mechanical Engineering, Electrical Engineering, and Financial Auditing. This quality survey must address the question: "How well does the quality control program conform to the contractor's manufacturing process?". The team can use the checklists presented in this chapter to verify the accuracy of what the contractor has written in the proposal about the contractor's quality management capability. This survey will usually require two or three days. With the checklist the QST can check on-site every aspect of the contractor's quality management process, such as quality personnel, quality policy and procedure, concern for quality, quality assurance, and so on.

C. CHECKLIST

The following checklist can be used for contractor evaluation. The answer to those questions that are applicable should be "YES" in order to expect desirable results. The following outlines is adapted from MIL-HDBK-50A [Ref. 10] and Petit [Ref. 18].

1. Quality

1.1 Quality Personnel

A. In Proposal

1.1.A.1 Are the quality related requirements, duties and responsibilities of all personnel identified?

1.1.A.2 Does the plan require the training of personnel performing activities affecting quality?

B. Past Performance

1.1.B.1 Are quality related job criteria specified in job descriptions to permit proper personnel selection?

1.1.B.2 Are personnel selected on the basis of capability, experience and the degree to which they fully qualify for the job?

1.1.B.3 Are personnel made aware of the consequences of poor job performance on other personnel and upon customer satisfaction?

1.1.B.4 Do the personnel performing the various quality functions have sufficient authority, responsibility, and freedom of action to identify and evaluate quality problems and initiate, recommend or provide solutions?

1.2 Quality Policy and Procedure

A. In Proposal

1.2.A.1 Does the established plan identify the organizational elements responsible for each of the various quality efforts and for overall quality assurance?

1.2.A.2 Does the plan reflect a control of all work operations and building processes?

B. Past Performance

1.2.B.1 Does management provide a work environment that encourages good quality performance, and verify that the combination of materials, equipment, personnel capability, instruction and supervision are capable of meeting requirements?

1.2.B.2 Does management generally review the competence of the quality program?

1.2.B.3 Will documented work instructions be made available and used for all work operations which affect quality?

1.2.B.4 Are documented work instructions complete and appropriate?

1.2.B.5 Are standards available for each work operation?

1.2.B.6 Are work instructions compatible with associated testing and inspection?

1.2.B.7 Do inspectors, managers and supervisors make proper use of work instructions?

1.2.B.8 Are work instructions reviewed on a systematic basis for completeness, currentness and worker conformity?

1.2.B.9 Are changes to work instructions controlled by the quality assurance department?

1.3 Concern for Quality

A. In Proposal

- 1.3.A.1 Does the plan provide for quick detection of inferior quality and for correction of the causes?
- 1.3.A.2 Is the quality control procedure to be used during the construction process specified in the contractor's proposal?

B. Past Performance

- 1.3.B.1 Is sufficient action taken to correct the causes of defects in products, facilities, and in functional areas such as design, manufacturing, testing and inspection?
- 1.3.B.2 Are analyses made to diagnose product deficiencies?
- 1.3.B.3 Is corrective action taken to stop unfavorable trends before defects occur?
- 1.3.B.4 Will subcontractors be responsible for required corrective action?
- 1.3.B.5 Are product examination and data analyses conducted on rework, scrap, subcontractor repair or use-as-is data to determine extent and reasons of defects?
- 1.3.B.6 Is the effectiveness of corrections reviewed and tracked?
- 1.3.B.7 Is management informed of the requirement and completion of corrective action?
- 1.3.B.8 Does the quality control procedure include documented work instructions, sufficient production equipment, and appropriate working tools?
- 1.3.B.9 Does evidence exist verifying that the products have satisfied all contractual requirements as to fit, form and function; including contractually required tests, at time of shipment?
- 1.3.B.10 Is there retest and reinspection of all items which are repaired, reworked or modified after product testing and are they reported to design engineering and manufacturing for resolution?
- 1.3.B.11 Are sufficient work and inspection instructions employed for the handling, storage and delivery of material?

- 1.3.B.12 Are handling, storage and delivery procedures monitored in compliance with quality program requirements?
- 1.3.B.13 Are there procedures and periodic schedules for the inspection of products in storage, and are these procedures sufficient to prevent deterioration or damage?
- 1.3.B.14 Is there a procedure to ensure that items, which can deteriorate or corrode during fabrication or temporary storage, are correctly cleaned and preserved?
- 1.3.B.15 Does all packaging provide adequate protection during storage?
- 1.3.B.16 Are all material to be stored or shipped correctly identified and labeled?
- 1.3.B.17 Are all shipments prepared in conformity with contractual requirements and applicable to government and carrier regulations?
- 1.3.B.18 Is the quality of equipment maintained during transit?
- 1.3.B.19 Are contractor developed statistical quality control and analysis plans available for review by the government?
- 1.3.B.20 Do contractor developed statistical quality control and analysis plans provide solid confidence and quality assurance?
- 1.3.B.21 Does the contractor have an effective system for distinguishing the inspection status of products?
- 1.3.B.22 Is the contractor's inspection status identification clearly different from that of the government?
- 1.3.B.23 Do contractor purchasing documents require inspection by the government of items provided by subcontractors only when the government requests?
- 1.3.B.24 Are copies of applicable purchasing documents provided to the government at the subcontractor's plant upon request?

1.4 Quality Assurance

B. Past Performance

- 1.4.B.1 Does the contractor provide records on previous experience in design, development and production of items similar to the item proposed?

- 1.4.B.2 Are the various types and classification of records to be collected recognized and are responsibilities recognized?
- 1.4.B.3 Is the minimum content prescribed for every type of record and is a minimum retention time specified?
- 1.4.B.4 Are there records of all necessary activities?
- 1.4.B.5 Are there effective means for insuring the currency, accuracy and completeness of the records available to government personnel, when requested?
- 1.4.B.6 Do inspection records contain only the number and kind of deficiencies product?
- 1.4.B.7 Where and how are other necessary data recorded?
- 1.4.B.8 If rejection is recorded, do records provide traceability to resolution actions?
- 1.4.B.9 Do management actions shows the analyses and uses of records?
- 1.4.B.10 Are approved and tested raw materials recognized and precisely segregated from those not approved or tested?
- 1.4.B.11 Is the test, inspection and monitoring of processed material applied systematically?
- 1.4.B.12 Are unsuitable monitoring methods or inspection procedures corrected rapidly?

2. Pricing and Financial Considerations

2.1 Price, Quality, and Cost Structure

A. In Proposal

- 2.1.A.1 Has the contractor justified his design and price on the basis of total life cycle cost?
- 2.1.A.2 Has the contractor included a Total Life Cycle Cost analysis in his proposal including a cost breakdown structure, a cost profile, etc.?
- 2.1.A.3 Has the contractor determined the specific quality cost data that he needs?

B. Past Performance

- 2.2.B.1 To obtain a true picture of value received, are the basic contractor and subcontractor cost data for purposes of price determination known?

2.2.B.2 Does the data identify both the cost of prevention and the cost of correction of defects?

2.2.B.3 Can the cost data be provided to the government when requested?

2.3 Financial Ability

A. In Proposal

2.3.A.1 Is there minimal financial risk of doing business with the contractor?

2.3.A.2 Have the analysis of Clout Ratio (buyer's annual order value/contractor's total annual sales), Current Ratio (current assets/current liabilities), and Quick Ratio (current assets less inventory/current liabilities) been done?

2.3.A.3 Have the analysis of Inventory Turnover (sales/inventory), and Collection Period (receivables/sales per day) been done?

B. Past Performance

2.3.B.1 Does the contractor provide evidence of past financial strength through auditable records?

2.3.B.2 Has the contractor ever had difficulty financing previous projects?

3. Performance

3.1 Technical Performance

A. In Proposal

3.1.A.1 Does the plan ensure conformity with contract requirements for proposing, approving and implementing engineering changes?

3.1.A.2 Does the plan ensure "on-time" delivery or retention of the data prescribed by the contract?

3.1.A.3 Does the plan sufficiently cover the contractor's responsibilities for providing required rights to data covering items that arise with his subcontractors?

B. Past Performance

- 3.1.B.1 Are there sufficient procedures for controlling all computer based documentation affecting product conformance?
- 3.1.B.2 Are there procedures for ensuring supplemental documentation is available and correctly controlled?
- 3.1.B.3 Is there complete contract conformity concerning proprietary rights to data?
- 3.1.B.4 Does the program sufficiently cover the contractor's responsibilities for providing required rights to data covering items that arise with his subcontractors?

3.2 Delivery History

A. In Proposal

- 3.2.A.1 Does the contractor commit to a specific delivery date?
- 3.2.A.2 Does the plan provide reason to believe that the project will be delivered on time?

B. Past Performance

- 3.2.B.2 Does the contractor provide evidence of experience in delivering high quality products in a timely manner and within cost?
- 3.2.B.3 Has the contractor provided delivery histories of all his products?

3.3 Technical Assistance

A. In Proposal

- 3.3.A.1 Does the plan ensure that products and services provided by subcontractors totally satisfy contract requirements?
- 3.3.A.3 Does the plan provide for the selection of subcontractors on the basis of their capability to produce quality products?

B. Past Performance

- 3.3.B.1 What are the contractor's procedures for selection of subcontractors?
- 3.3.B.2 Is objective quality evidence provided by the subcontractor and is it used to ensure effective and economical quality control?

- 3.3.B.3 Does the contractor provide adequate source inspection for control of his subcontractors?
- 3.3.B.4 Does the contractor review his subcontractors' quality efforts at intervals compatible with the complexity and quality of the product?
- 3.3.B.5 How does the contractor communicate requirements to subcontractors?
- 3.3.B.6 Are there sufficient procedures for evaluating the quality of all supplies and services furnished to the contractors?
- 3.3.B.7 Are there sufficient procedures for providing subcontractors with appropriate data concerning poor quality?
- 3.3.B.8 Are there sufficient procedures for ensuring that subcontractors correct all nonconformances?
- 3.3.B.9 Does the contractor require his subcontractors to have effective control of product quality?
- 3.3.B.10 Do the contractor's purchasing documents include all of an item's routine and special requirements for design, manufacturing, and testing?
- 3.3.B.11 Do purchasing documents provide for prime contractor or government source inspection when appropriate?
- 3.3.B.12 Are requirements for essential tests and inspections of raw materials identified in purchasing documents?
- 3.3.B.13 Is complete and suitable control of design changes dictated to all subcontractors?
- 3.3.B.14 Are the essential instructions provided for any required direct shipments from subcontractors' plants to the government?

4. Inspection Capabilities

4.1 Production Processing

A. In Proposal

- 4.1.A.1 Does the plan conform with the contractor's production facility?

4.1.A.2 Does the production process in the contractor's plant provide evidence that the contractor has the capability to construct that project?

B. Past Performance

4.1.B.1 Does the contractor inspect subcontractors' material to the extent essential?

4.1.B.2 Does the contractor/subcontractor ensure that raw materials conform to the suitable chemical, physical, and other technical requirements, using laboratory analyses as essential?

4.1.B.3 Does the contractor/subcontractor have efficient controls for avoiding the use of nonconforming materials?

4.1.B.4 Are all production processes achieved under controlled conditions?

4.1.B.5 Do the work instructions provide criteria for determining whether design, manufacturing, and fabrication work is acceptable or unacceptable?

4.1.B.6 Does the quality program monitor both the issuance of work instructions and conformity with them?

4.1.B.7 Are physical examinations, tests or measurements of materials and products conducted for each work operation?

4.1.B.8 When direct inspection of material is not expedient, does the program provide for indirect control by observing the process?

4.1.B.9 Are both process control and physical inspection used when either one is inadequate, or when required by the contract?

4.1.B.10 Does a system exist which traces the results of verifications of out of control conditions and trends with inputs to be aware of functions needing correction?

4.1.B.11 Is the test, inspection and monitoring of processed material applied systematically?

4.1.B.12 Are unsuitable monitoring methods or inspection corrected rapidly once detected?

4.1.B.13 Is conformity with documented inspection methods complete and continuous, and are corrective actions taken when noncompliance happens?

- 4.1.B.14 Are approval and rejection criteria provided for all inspections and monitoring actions?
- 4.1.B.15 Does the contractor have an efficient system for controlling nonconforming material?
- 4.1.B.16 Does the contractor correctly specify, isolate and dispose of nonconforming material?
- 4.1.B.17 Are the procedures for repair and rework of nonconforming material documented and acceptable to the government?
- 4.1.B.18 Are scrap and rework cost and loss data sustained and available to the government for review?
- 4.1.B.19 Do repair and rework activities conform with documented procedures?

4.2 Manufacturing Equipment

A. In Proposal

- 4.2.A.1 Does the plan dictate the research needed for developing all the advanced or new testing and inspection techniques needed?
- 4.2.A.2 Does the manufacturing equipment conform to the plan?

B. Past Performance

- 4.2.B.1 Has action been taken to conduct the controls for special requirements compatible throughout manufacturing, testing and inspection?
- 4.2.B.2 Are the gages, testing and measuring equipment essential to ensure that products satisfy technical requirements available and used?
- 4.2.B.3 Is this test and measuring equipment correctly sustained?
- 4.2.B.4 Are these devices initially certified and latterly inspected on a regular basis to conclude that they are of the needed accuracy?
- 4.2.B.5 Does the contractor ensure that his subcontractors have a system which verifies the accuracy of their test and measuring equipment?

IV. APPLICATION OF TLCC AND TQM TO SHIPBUILDING IN THE INDONESIAN NAVY

A. BACKGROUND

1. TLCC as a Tool for Measuring Cost Performance

The government and other institutional forms of organizations typically tend to buy the least expensive product available. When holding competitive bidding among contractors, the government has generally chosen the lowest bidder. This can be inappropriate since it is a decision-making process based primarily on a short-range perspective where only the procurement cost of a new system is considered. A more appropriate decision making process is to consider TLCC because it is a tool for measuring cost performance from a long-range perspective. It covers not only the procurement cost, but also the cost of operation, maintenance and disposal.

In recent years, as budgets have become tighter the government has realized that the procurement price of a project represents only a part of its TLCC. The ownership costs such as the operation and maintenance costs have frequently far exceeded the procurement cost and have therefore imposed strict limits on the amount of equipment that could be afforded in the future. As a result, the government has become aware that a low procurement price frequently does not mean a low TLCC.

2. Use of TLCC

Using TLCC has six primary benefits. All of the benefits are relevant to the government procurement process. Those six uses are as follows:

- a. It focuses on long-range cost performance (versus the more traditional short-range cost performance), as a result decisions can be made based on more complete information with less risk involved;
- b. It focuses on total cost visibility, which enables the identification of high cost system elements, equipment or processes;

- c. It aids in the early identification of potentially high risk areas, and enables the elimination of the possible causes of risk;
- d. It facilitates selection among competing contractors as the prime criterion for contractor selection;
- e. It enables evaluation of the operating and maintenance costs of various approaches to the logistics concept of a system over its entire life cycle; and
- f. It enables comparison of competing program by making it possible to compare the costs of a number of alternative ways of meeting an operational requirement.

3. Low TLCC is a Better Criterion than Low Procurement Price

In the United States the concept of TLCC was initiated by the US Department of Defense and first used in its procurement policy in the early 1960s. The objective of forcing the contractor to use the TLCC concept in the design proposal is to minimize the TLCC. The selection of the lowest procurement price is now seen as false economy, and low TLCC is regarded as a better criterion.

4. Purpose of the Design Review and Contractor Review Checklists

To obtain a quality product, both a high quality design and a contractor who can build that design are required. Evaluation of the design must consider both the conformity of the design to specification and its TLCC. In addition, careful evaluation of the contractor will assess his capability to bring the design into reality. This is the purpose of the Design Review and Contractor Review Checklists.

B. BUILDING WARSHIPS IN THE INDONESIAN NAVY

1. The Indonesian Navy's Fleet

The Indonesian Navy has a fleet of more than one hundred ships of different types from different countries. Great effort and cost for operations, maintenance and logistics support are required, because the ships are not standardized. However, they also have an advantage, since they do not depend on support from one particular country. Some examples of them are: Patrol Submarines from West Germany, Frigates from the United

Kingdom and the Netherlands, Corvettes from the Netherlands, Fast Attack Craft - Missile from South Korea, Landing Ship Tank from the US and South Korea, Tankers from Yugoslavia, and so on. They are a mixture of new construction and secondhand ships.

Before the establishment of PT PAL (PT Pabrik Kapal Indonesia, Indonesian Shipbuilding Industry) in Surabaya on 15 April 1980, all Indonesian Navy's ships were bought from other countries. That meant the Indonesian Navy could not do anything about the design or construction of secondhand ships because they were already built. However, for new construction that was built outside Indonesia, there was a Navy task unit that acted as a user representative during the ship's development process. The task unit could make known the design and weapons systems requirements the Indonesian Navy desired. The Commander of the Navy task unit usually was a Colonel or a Rear Admiral. He had at least three assistants or officers who were experts in naval engineering, mechanical engineering and electrical engineering. They were responsible to the Commander for controlling the project to ensure there was no deviations from the technical specifications or requirements. The ranks of the officers were between Lieutenant Commander and Captain. The task unit was involved in the project from conceptual design to ships' commissioning.

2. The Process of Building Fast Patrol Boats

In 1982 the Lurssen factory from West Germany gave a license to Indonesia to build Fast Patrol Boats (FPB) with the "progress manufacturing method" in an effort to transfer technology to Indonesia. The progress manufacturing method means that for the first ship, all the components/parts of the ship were made in Germany, then the components were shipped to PT PAL Surabaya where the ship was fully constructed. As more components of the ships are built in Indonesia, the local content increases gradually. Some machinery, equipment, electronic components, and weapons are still imported from abroad. During the ship development process, there is a Navy task unit that acts as the user representative. For new constructions that are built in Indonesia, the Commander of Navy task unit is a Commander, and he is administratively responsible to the Indonesian

Department of Defense and Security (DoDS), but he is also technically responsible to the Chief of Staff of the Navy. His responsibility is to control the process of building the ship as a whole and to ensure compliance with the technical specifications agreement. He has four assistants/officers who are responsible for Machinery, Ship Structure, Electronics and Weapon Systems, and Personnel Training (Ship's crew and Base Maintenance Team). The rank of those officers is Commander also. Administrative support is provided by a junior officer, petty officers and civilians.

At the writing of this thesis, the concept of TLCC has not been used in the PT PAL, but the Total Quality Concept of conformance with ISO-9001 has been implemented. Computer Aided Design and Computer Aided Manufacturing have also been implemented. The delivery history of the ship is as follows: the first ship was delivered within 36 months and subsequent ships were delivered intermittently every five months. Five versions of FPB have been built:

- a. NAV: Anti-submarine warfare version with torpedo tubes and sonars;
- b. NAV II: Anti-aircraft warfare version with an augmented gun armament, and improved surveillance and fire control radar, but without torpedo tubes and sonar;
- c. NAV III: Search and Rescue version very lightly armed, but with a 13 x 7.1-m helicopter deck;
- d. NAV IV: Presidential Yacht manned by a special unit; and
- e. NAV V: Surface warfare version with a second 57 mm gun aft and an integrated combat data system.

3. The Process of Acquiring Warships in the Indonesian Navy

The Navy's Power Development Plan is formulated based upon the Indonesian Armed Forces Strategic Plan. It specifies the military equipments and new weapon systems needed by the Indonesian Armed Forces (IAF) for the next five years. The DoDS

submits a Letter of Intent (LOI) to PT PAL which is a preliminary order for the ships needed to be built for the Navy over the next five years.

The Indonesian Armed Forces Headquarters (IAFHQ), by direction of the DoDS, will develop a Term of Reference (TOR) which contains the general requirements for both types of ships. That TOR will be sent to the PT PAL. After receiving that TOR, the designer of PT PAL will make a design proposal and send that proposal to the DoDS. The representative from the IAFHQ (usually including Navy officers) will evaluate the proposal to determine if it will satisfy the Navy's needs. This is the time where the Design Review can be used as guidance by the representative of the IAFHQ to evaluate and to determine whether the PT PAL has the right design or not. Also, the Contractor Review can be used to check the capability of PT PAL by conducting a quality survey in PT PAL's facility. The Navy officers who are in charge of the representative of the IAFHQ can make suggestions and modifications on the design or manufacturing process in PT PAL's facility if there is something that does not conform with the requirements. After PT PAL makes corrections and everything is clear, the design becomes the Technical Specification. This Technical Specification becomes one of the enclosures in the contract agreement.

The DoDS will submit a letter of order to the Directorate General of Material, Facility and Merit (DGMFM) to conduct intra-departmental negotiations with PT PAL. After the negotiations are finished, then the DoDS will send the results to the Minister of Finance (MOF) for preparation of the budget. If the budget has already been prepared, then the MOF will send a letter to the DoDS in order that the contract can be executed. Then the Minister of DoDS and the Main Director of PT PAL sign the contract.

By DoDS regulation, a Navy representative is always present in every activity of acquiring a ship. If PT PAL builds a copy of the ship or uses a different design for other services like the Indonesian Police, the Navy will act as an intermediary. Consequently, in every activity of building a ship which is ordered by the DoDS and supplied by PT PAL,

there must be Naval officers involved. In this process the Design Review and the Contractor Review can be used to evaluate the design and the capability of PT PAL.

C. EXAMPLES OF PROJECT MANAGEMENT USING THE DESIGN REVIEW AND CONTRACTOR REVIEW CHECKLISTS

1. The Fatahillah Class

In August 1975, the construction of three new "Fatahillah" Class Combined Diesel or Gas Turbine (CODOG) corvettes or light frigates was ordered from the Wilton Fijenoord shipyard in the Netherlands. These corvettes' design was similar to NATO's Standard Frigates and the design had already incorporated the concept of TLCC. This was the first time the Indonesian Navy used the Planned Maintenance System adopted from the Netherlands Navy. This system uses the preventive maintenance approach where all equipment is checked and maintained properly according to a schedule. This approach does not wait until the equipment is out of order before initiating repairs. Also, there were three separate levels of maintenance: Depot Maintenance, Intermediate Maintenance, and Organic Maintenance. Organic Maintenance is done by the crew, with the concept of repair-by-replacement. Intermediate Maintenance is done by the Base Maintenance Team or the contractor. Depot Maintenance is done by the shipyard. For example, the diesel generator requires changing the machine oil every 200 hours and is done by the crew; changing the vulcan coupling as needed is done by the Base Maintenance Team or contractors, because it requires special tools; and general overhauls (every 18,000 hours) are done by the shipyard. By this illustration it is obvious that by design this corvette ship has already considered the cost of operation and maintenance over the life of the ship until its disposal.

2. The Van Speijk Class

In 1986 the Indonesian Navy signed an agreement with the Royal Netherlands Navy for transfer of four of Van Speijk Class frigates with an option on two more. Different from the Fatahillah Class, these ships were not new construction, but secondhand ships. These ships were bigger than Fatahillah Class, however both classes

had almost the same capabilities. It is the author's opinion that the Indonesian Navy decided to buy these ships due to budgetary problems since they were cheap.

Subsequently it has been discovered that the cost of operation was huge, because the fuel consumption of these ships was 65,000 liters per day. A contract of sale for the last two ships of this class was signed in 1989.

3. How Design Review Can Give Lower TLCC

The cost comparison below is between the Fatahillah Class (FC) which used the TLCC and the Van Speijk Class (VSC) which did not use TLCC in the design of the ships. The data in this comparison are based upon the estimation and experience of the author. The following assumptions are made: The life cycle is 25 years, depot maintenance is done every five years, each ship is operated six months a year, and each ship is at sea for 125 days.

The criteria of the cost comparison are as follows:

- a. Acquisition price: Fatahillah Class (FC) was \$50,000,000 and Van Speijk Class (VSC) was \$5,000,000.
- b. Depot overhaul every five years: the cost of each FC Depot was \$1,250,000 and the VSC's cost \$2,500,000.
- c. The Organic and Intermediate maintenance budget for the FC was \$400,000 and that of the VSC was \$600,000 per year.
- d. Fuel consumption: each day a FC ship consumes 20,000 liters, the VSC consume 65,000 liters. Each year each ship is operated for six months and during that period each ship is at sea for 125 days. The fuel's price is \$0.25 per liter.
- e. Oil consumption: each day both ships consume amount 75 liters of oil. The oil's price is \$1.25 per liter and each year both ships are at sea for 125 days.
- f. Salaries: the FC crew size is 89 and the VSC crew size is 180. The salaries are different between officers, petty officers and enlisted personnel, but it is assumed the average salary is \$200 per month. The salaries are paid regardless of whether the ship is at sea or not.

- g. Rations: the Indonesian Navy provides a basic allowance of food, health care, recreation, etc. for all of the ship's crew during operation. The amount is the same for each crew member: \$77 per month per crew member for the six months per year the ship operates.

| Fatahillah Class | | |
|----------------------------|---|----------------------|
| 1. Acquisition Price | | \$ 50,000,000 |
| 2. Depot overhaul | $5 \times 1,250,000 =$ | \$ 6,250,000 |
| 3. Org. & Int. Maintenance | $25 \times 400,000 =$ | \$ 10,000,000 |
| 4. Fuel consumption | $20,000 \times 0.25 \times 125 \times 25 =$ | \$ 15,625,000 |
| 5. Oil consumption | $75 \times 1.25 \times 125 \times 25 =$ | \$ 292,969 |
| 6. Salaries | $89 \times 200 \times 12 \times 25 =$ | \$ 5,340,000 |
| 7. Rations | $89 \times 77 \times 6 \times 25 =$ | <u>\$ 1,027,950</u> |
| Total cost for 25 years | | <u>\$ 88,535,919</u> |

| Van Speijk Class | | |
|----------------------------|---|----------------------|
| 1. Acquisition Price | | \$ 5,000,000 |
| 2. Depot overhaul | $5 \times 2,500,000 =$ | \$ 12,500,000 |
| 3. Org. & Int. Maintenance | $25 \times 600,000 =$ | \$ 15,000,000 |
| 4. Fuel consumption | $65,000 \times 0.25 \times 125 \times 25 =$ | \$ 50,781,250 |
| 5. Oil consumption | $75 \times 1.25 \times 125 \times 25 =$ | \$ 292,969 |
| 6. Salaries | $180 \times 200 \times 12 \times 25 =$ | \$ 10,800,000 |
| 7. Rations | $180 \times 77 \times 6 \times 25 =$ | <u>\$ 2,079,000</u> |
| Total cost for 25 years | | <u>\$ 96,453,219</u> |

Thus, TLCC for Fatahillah Class < TLCC for Van Speijk Class.

Conclusion: Initially the FC price is ten times the VSC price, but within 25 years of operation, the TLCC of VSC is about eight million dollars higher than the TLCC of FC. Even if the VSC ships were free, their TLCC still exceeds the TLCC of the FC ships by three million dollars.

Lessons learned by this experience are that the TLCC should be calculated as early as possible in the decision making process and it can be used not only for ordering new construction, but also for purchasing second hand ships. If the checklist had been used, it would have resulted in a better decision based on lower TLCC.

The following questions from the Design Review Checklist (identified by question number) would have appropriately guided a QST:

- a. 1.1.6 In the evaluation of alternative technology applications, have life cycle considerations been employed and have peculiar support requirements been identified?

This question would have directed a QST to realize that the FC ships have lower TLCC compared to the VSC even though the FC acquisition price is higher.

- b. 2.1 Have the anticipated levels of maintenance been identified and defined?

This question would have directed a QST to calculate and realize that that the depot overhaul cost of the VSC was two times higher and the organic and intermediate maintenance costs were one and half times higher compared to the FC ships and thus would incur greater TLCC.

- c. 14.1.4 Is the planned fuel consumption reasonable?

This question would have directed a QST to realize that the fuel consumption of the VSC ships was not reasonable compared to the FC ships and thus would incur greater TLCC.

- d. 28.1 Have operational and maintenance personnel quantity and skill requirements been specified?

This question would have directed a QST to realize that salaries and rations costs of the VSC ships were almost two times higher compared to the FC ships and thus would incur greater TLCC.

These four sample questions show how the Design Review Checklist would guide the QST in selecting the ship design that would result in low TLCC.

4. How Contractor Review Can Give Lower TLCC

The order-winning criterion for project management is capability. Capability cannot be produced in one day. What the contractor has done in previous jobs is the best indicator of what he will do on the next job. The Contractor Review can be done in a quality survey that should address the question: "How does the contractor's quality

program conform to the required manufacturing process?. ” Beginning at the contractor’s facility gate the quality of a contractor as a whole is reflected. For example, when the author was in the Wilton Fijenoord shipyard (Netherlands) in 1978, anybody who wanted to enter the gate had to show his identification (ID). If a person forgot his ID, even if the gatekeeper was familiar with that person, he was not permitted to enter. This simple event shows the sense of quality and responsibility of the personnel (in this case the gatekeeper). It also reflects the strength of their security program and this attitude is usually reflected throughout the contractor’s quality management program. By using the Contractor Review as a reference, this kind of thing must be looked carefully and evaluated by the team in the contractor facility.

The main objective of the Contractor Review Checklist is to verify the reality of every aspect of the contractor’s quality management program in the contractor facility by evaluating his proposal and his past performance. The following example questions from the Contractor Review Checklist (identified by question number) would have appropriately guided a QST visiting the Wilton Fijenoord shipyard:

- a. 1.1.A.1 Are quality related requirements, duties and responsibilities of all personnel identified?

The question would have directed a QST to observe that the personnel at Wilton Fijenoord know their job requirements, duties, and responsibilities relative to quality.

- b. 2.1.A.1. Has the contractor justified his design and price on the basis of Total Life Cycle Cost?

This question would have directed a QST that the design justification should not be based on acquisition price but on Wilton Fijenoord’s capability to achieve a low TLCC.

- c. 2.1.A.2 Has the contractor included a Total Life Cycle Cost analysis in his proposal including a cost breakdown structure, a cost profile, etc?

This question would have directed a QST to verify the reasonableness of Wilton Fijenoord's cost estimates.

- d. 2.3.A.1 Is there minimal financial risk of doing business with the contractor?

This question would have directed a QST to audit Wilton Fijenoord's financial capability from previous projects and to verify that Wilton Fijenoord had the financial capacity to complete the product without compromising on quality.

- e. 3.1.A.1 Does the plan ensure conformity with contract requirements for proposing, approving and implementing engineering changes?

The question would have directed a QST to observe how Wilton Fijenoord's procedures for engineering changes would minimize cost, rework and repair, and thus ensure a quality product is produced.

- f. 3.3.A.1 Does the plan ensure that products and services provided by subcontractors totally satisfy contract requirements?

This question would have directed a QST to verify that the subcontractors were held to the same standards of performance as the Wilton Fijenoord shipyard.

- g. 4.1.B.1 Does the contractor inspect the subcontractors' materials to the extent essential?

This question would have directed a QST to observe Wilton Fijenoord's quality management procedures from the very beginning of the process, because good quality can be achieved only with good raw materials in order to prevent rework or repair.

The example questions above show how the Contractor Review Checklist would guide the QST in selecting the best contractor based upon the contractor's capability.

V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

Project management is a method of planning, monitoring and controlling an assigned job to achieve the desired results on schedule within a specified cost. Project management is needed to develop a new weapon system, like a warship, or a tank. The goal is to build a high quality project. Often organizations tend to buy the least expensive project available. When holding competitive bidding among contractors, the government has generally chosen the lowest bidder. This is inappropriate. The decision-making process has typically been based primarily on short range cost performance since the cost of a new system has been based solely on the procurement cost. The correct way would be to use the Total Life Cycle Cost (TLCC), because TLCC is a tool for measuring cost performance in long range planning. It covers not only the procurement cost, but also the cost of operation, maintenance and disposal.

In recent years, as its budget has become tighter, the government has realized that the procurement price of the project represents only a part of its TLCC. The ownership costs such as the operation and maintenance costs have frequently far exceeded the procurement cost. As a result, the government has become aware that a low procurement price frequently does not mean a low TLCC.

In the United States, the concept of TLCC was initiated by the US Department of Defense and was first used in its procurement policy in the early 1960s. The objective of requiring the contractor to use the TLCC concept in the design's proposal is to minimize the TLCC. The selection of the lowest procurement price is now seen as false economy, and the lowest TLCC is now regarded as a better criterion.

Broadly speaking, quality is defined as adherence to specifications and high quality is defined as minimum variability around those specifications. For a project like building a ship, the TLCC can be considered as a function of four things: design, construction, operation and maintenance. However, the selection of the design and the contractor are

one-time decisions, and cannot be changed over the life of the ship. Operation and maintenance on the other hand, are on-going management decisions, yet they are driven by the design and how well the contractor builds the ship. Consequently, to achieve a high quality project the government must focus on carefully reviewing the contractor's design and the contractor's capability. To have the lowest TLCC, the right design and the right contractor must be selected. This thesis presents a Design Review Checklist and a Contractor Review Checklist that can be used for reviewing the contractor's design and contractor's capability.

The Indonesian Navy has a fleet of more than one hundred ships of different types from different countries. Great effort and cost for operations, maintenance and logistic supports are required, because the ships are not standardized. They are a mixture of new construction and secondhand ships.

Before the establishment of PT PAL (PT Pabrik Kapal Indonesia, Indonesian Shipbuilding Industry) in Surabaya on 15 April 1980, all Indonesian Navy ships were bought from other countries. This means that the Indonesian Navy was often not involved in the design or construction of the secondhand ships because they were already built. However, for new construction that was built outside Indonesia, there was a Navy task unit during the ship's development process. The task unit could make known the requirements which the Indonesian Navy desired.

In 1982, the Lurssen factory in West Germany gave a license to Indonesia to build Fast Patrol Boats with the "progress manufacturing method" as an effort in technology transfer. Eight Fast Patrol Boats have been built. At the writing of this thesis, the concept of TLCC has not been used in PT PAL, however the Total Quality concept of conformance with the ISO-9001 and use of Computer Aided Design and Computer Aided Manufacturing have been used.

B. CONCLUSIONS

The TLCC should be calculated as early as possible in the decision-making process. Both the Design Review and the Contractor Review should be used with TLCC

as the criterion for contractor selection. In 1975, the Indonesian Navy contracted for three new "Fatahillah" class corvettes or light frigates to be built at the Wilton Fijenoord shipyard in the Netherlands. This is a design unique to the Indonesian Navy because there is no other country that has ships of the Fatahillah class. Fortunately, the design from the shipyard had already been done using the concept of TLCC, so relatively low operation and maintenance costs were already planned into the design.

In 1986 the Indonesian Navy signed an agreement with the Royal Netherlands Navy for transfer of four Van Speijk class type Frigates with an option for two more. By using the Design Review Checklist, the concept of TLCC can still be applied even if the design has already been built. By using the checklist, the author shows that the TLCC of the Van Speijk Class (VSC) is higher by almost \$8,000,000. than the Fatahillah Class (FC) over 25 years. In fact, even if the VSC ships were free, their TLCC still exceeds the FC TLCC by \$3,000,000 each. The Design Review Checklist can guide the decision maker to ask the right questions and consider all of the necessary issues to ensure that the TLCC of a project is the lowest.

To achieve the lowest TLCC, it is not enough to use only the Design Review Checklist. The objective is not only to choose the contractor who can make the best design, but who also has the capability to build the design and bring a high quality concept into reality. The Contractor Review Checklist can be used to evaluate the contractor's capability. The main purpose in using the checklist is that by looking carefully, interviewing, and testing if necessary in the contractor's plant, the Indonesian Navy's Quality Survey Team can determine whether or not the contractor has the capability to make the project.

Using both the Design Review and the Contractor Review Checklists decision makers in the Indonesian Navy can choose the design and the contractor that will result in ships with low TLCC.

C. RECOMMENDATIONS

The author recommends the following actions be taken:

1. TLCC Should Be Used in Procurement Policy

The concept of TLCC should be used in all procurement policies. For procurement of a new weapons system, such as a new warship for the Indonesian Navy, the concept of TLCC should be used. It is recommended that the decision makers in the Indonesian Navy use the checklists presented in this thesis to choose the design and the contractor that will result in ships with low TLCC. The Design Review Checklist can be used in evaluating the contractor's proposal and the Contractor Review Checklist can be used to evaluate the contractor's capability.

2. Quality Survey Teams Should Be Set Up

A Quality Survey Team (QST) should be set up for each project. The QST should be made up of three Naval Officers whose ranks are between Lieutenant Commander and Colonel. They should be specialists who have at least 11 years experience and a degree in Naval Engineering with specialization in Structure design; Mechanical Engineering with specialization in Propulsion and Auxiliaries Systems; and Electrical Engineering with specialization in Power, Sensor and Weapons Systems. The QST should be headed by a project manager (PM) whose rank is at least Colonel or Rear Admiral, who has experience at sea as the Commanding Officer of a combatant ship such as a submarine, frigate and corvette.

3. The Design Review Checklist Should Be Used

Before using the Design Review to evaluate the contractor's design proposal, the PM needs to choose the team members of QST, consisting of three officers who have specialties in Naval, Mechanical and Electrical Engineering. The PM assigns their roles and tasks, provides them with guidelines such as the Design Review Checklist and other criteria that are necessary, and conducts an overview meeting which describes how the evaluation will be done. The evaluation will start with an individual review, where each

member examines the design based on his specialty and prepares an opinion about the design. A team review will follow, where all members examine the design overall and prepare a grade for the design proposal.

4. The Contractor Review Checklist Should Be Used

Unlike the Design Review, the Contractor Review needs a financial officer to evaluate the financial capabilities of the contractor. The PM provides the QST with guidelines such as the Contractor Review Checklist and other criteria that are necessary. The QST conducts its survey together at the contractor's facility. During this survey each member with the guidelines from the Contractor Review Checklist will look carefully, interview and test if necessary in accordance with their specialty. Through these means the QST can determine whether or not the contractor has the capability to successfully complete the project, and can grade the contractor's capability. The contractor's capability grade combined with the contractor's design grade will constitute an overall grade for the contractor's proposal that will be submitted to the PM. The PM's recommendation will be sent to the Chief of Staff of the Navy who will decide which contractor will be awarded the contract.

APPENDIX A. SYSTEM SPECIFICATION

The system specification is the top level specification for the ship. A specification is a description of the essential technical requirements for items, materials, or services that includes the verification criteria for determining whether these requirements are met. A specification supports the development and life cycle management of the item, material, or service described.

Specification are classified by entity and by type. By entity, there are five level of specifications: (1) system specification: it can be anything that somebody wants to make it, such as a ship, (2) item specification: a piece that make up a system, (3) software specification: it is also an item, but it is so different from others; it is like a program different than hardware (4) process specification: how to do a particular process, and (5) material specification: how to make a particular material.

By type, there are two kinds of specifications: (1) performance specification: it describes what is the need, do not tell the contractors how to make them, (2) detail specification: do it with the way that the government tell the contractors, no more no less. System specification is almost always a performance specification. It is assumed that each contractor at least makes a top level specification or system specification in his proposal. Based upon their system specification the government will evaluate them.

When establishing requirements, the government should follow these general principles: (1) requirements shall represent the actual necessary needs of the government. (2) requirements shall be described in a such a way to encourage competition, (3) requirements shall be clear and provide a definite basis for rejection or firm criteria for acceptance based on testing or examination.

The requirements of a system specification are outlined on the following five pages. This outline is adapted from MIL-STD-961D, APPENDIX A [Ref.11].

SYSTEM SPECIFICATION

1. **SCOPE.** *List the name and identifiers of the system covered. Briefly describe the system and identify its immediately subordinate entities.*
2. **APPLICABLE DOCUMENTS.** *List all referenced specifications, standards, handbooks, drawings, and other publications; both government and non-government. This listing does not establish any requirements.*
3. **REQUIREMENTS.** *Define the requirements that the system must meet to be acceptable. State requirements in such a way that an objective verification can be defined and a definitive basis is provided for acceptance or rejection.*

FUNCTIONAL AND PERFORMANCE REQUIREMENTS.

MISSIONS. *Describe the missions of the system to the extent that they effect design requirements. Include tactics, system deployment, operating locations, and facilities when pertinent.*

THREAT. *Describe the characteristics of potential targets, enemy weapons, and other threat considerations that affect system design.*

REQUIRED STATES AND MODES. *Identify the states or modes (idle, ready, training, wartime, peacetime, etc.) that the system is required to operate in. Correlate requirements below with these states or modes.*

CAPABILITY REQUIREMENTS. *In individual subparagraphs, identify all of the requirements associated with each capability or function of the system. Requirements shall be stated in measurable terms and include allowable deviations based on operating conditions. Where applicable, they should also address required behavior under unexpected or "out of bounds" conditions, and provisions for providing continuity of operations in the event of emergencies.*

RELIABILITY. *State the reliability requirements numerically (with confidence levels, if appropriate). Initially, reliability may be stated as a goal and a lower minimum acceptable value.*

MAINTAINABILITY. *State the maintainability requirements numerically (mean time to repair, maintenance man-hours per flight hour, etc.). Initially, maintainability may be stated as a goal and a higher maximum acceptable value. Include a reference to logistic requirements in this specification which affect the maintainability requirements.*

DEPLOYABILITY. *State the deployability requirements in terms of transportation of a specific number of entities over a specific distance for a specific period of deployment.*

AVAILABILITY. *State the extent to which the system shall be in an operable and committable state at the start of the mission(s) when the mission(s) is called for at an unknown (random) point in time.*

ENVIRONMENTAL CONDITIONS. *In individual subparagraphs specify environments (climate, electromagnetic, shock, vibration, noise, noxious gases, chemical agents, biological agents, nuclear weapon effects, etc.) that the system is expected to experience in shipment, storage, service, and use. State whether the system shall withstand or be protected against the specified environments. For systems which include software, specify the computer hardware and operating system in which the software must run.*

SYSTEM SPECIFICATION (con't)

TRANSPORTABILITY. *Identify requirements for transportability (weight, size, etc.) that are necessary to permit employment and logistic support. Also identify elements of the system that will be unsuitable (i.e., oversize, hazardous, delicate) for normal transportation methods.*

MATERIALS AND PROCESSES. *In separate subparagraphs, state requirements for materials and processes to be used in the system; and also requirements which would form the basis for development of new processes and materials specifically for this system.*

TOXIC, HAZARDOUS SUBSTANCES AND OZONE DEPLETING CHEMICALS. *If unavoidable, specify which toxic, hazardous substances and ozone depleting chemicals may be used.*

RECYCLED, RECOVERED OR ENVIRONMENTALLY PREFERABLE MATERIALS. *If applicable, state: "Recycled, recovered, or environmentally preferable materials should be used to the maximum extent possible provided that the material meets or exceeds the operational and maintenance requirements, and provides economically advantageous life cycle costs."*

ELECTROMAGNETIC RADIATION. *State requirements pertaining to electromagnetic radiation in terms of performance, design (including grounding), and interface considerations.*

NAMEPLATES OR PRODUCT MARKINGS. *State requirements pertaining to nameplates or markings, special markings for function or identification coding, and the use of stamped or imprinted information on the system.*

PRODUCIBILITY. *State requirements for selection of fabrication and inspection techniques, design parameters, and tolerances which would enable the system to be fabricated, assembled, inspected, and tested economically and with repeatable quality.*

INTERCHANGEABILITY. *State requirements for the levels of assembly at which components should be interchangeable or replaceable.*

SAFETY. *State requirements to preclude or limit hazards to personnel, equipment, and the physical environment. Identify safety characteristics unique to the system which constrain the design due to hazards in assembly, disassembly, test, transport, storage, operation, maintenance, or disposal not addressed by standard service and industrial practices. Address "fail safe" and emergency operating restrictions. State health and safety criteria, including physical, mechanical, biological, and explosive effects.*

HUMAN FACTORS ENGINEERING. *State human factors engineering requirements for the system. Highlight those areas, stations, or equipment that require concentrated human engineering attention due to the sensitivity of the operation, criticality of the task, or serious consequences of human error. Include considerations for human information processing capabilities and limitations, foreseeable human errors under both normal and extreme conditions, and implications for the total system environment (including training, support, and operational environment).*

SECURITY AND PRIVACY. *State security/privacy requirements that are basic to the design with respect to the operational environment of the system, and security requirements necessary to prevent access to the internal operating areas of the system and compromise of sensitive information or materials. Address the security/privacy environment in which the system will operate, the type and degree of security or privacy to be provided, the security/privacy risks the system should withstand, the security/privacy risks the system should withstand, the security/privacy policy that should be met, the security/privacy*

SYSTEM SPECIFICATION (con't)

accountability the system should provide, and the criteria that should be met for security/privacy certification or accreditation.

COMPUTER RESOURCE REQUIREMENTS.

COMPUTER HARDWARE RESOURCE UTILIZATION REQUIREMENTS. *State requirements on the system's computer hardware resource utilization, such as maximum allowable use of processor capacity, memory capacity, input/output device capacity, auxiliary storage device capacity, and communications/network capacity. Also state conditions under which the resource utilization is to be measured.*

DESIGN AND IMPLEMENTATION CONSTRAINTS. *State requirements that constrain the design and implementation of the system, such as use of particular software architecture, design or implementation standards, programming language, software units, government/acquirer furnished property (equipment, information, software), anticipated areas of growth or changes.*

SOFTWARE PORTABILITY. *State requirements for the replication, distribution, and installation of new versions of software, and system requirements which will permit minimum cost and time impacts in these areas. Include all logistic support considerations required for fielding new versions of software.*

SOFTWARE SUPPORTABILITY. *State requirements for software supportability; for integration or use of existing software support capabilities; for development or delivery of added support resources; for any limitations on the use of particular support facilities, computer equipment or software; and for use of a particular programming language.*

SOFTWARE QUALITY FACTORS. *In individual subparagraphs, specify each software quality factor (i.e., reusability, testability, usability) that the software in this system must achieve.*

LOGISTICS. *Specify logistic considerations and conditions that will apply to the system. Include maintenance considerations, software support, modes of transportation, supply system requirements, and impact of existing facilities and equipment.*

PERSONNEL AND TRAINING.

PERSONNEL. *Specify personnel requirements which must be integrated into the system's design. Include skills and numbers of personnel that should be allocated to operation, maintenance, and control of the system or item, and numbers and skills of support personnel for each operational mode and the intended duty cycle, both normal and emergency.*

TRAINING. *State restrictions on the type of training to be used for the system or item; constraints on the use of government training facilities and equipment; required capabilities of training devices to be developed, characteristics of the training devices, and training/skills to be developed through use of the training devices; and limitations on training duration and locations.*

REQUIREMENTS TRACEABILITY. *Provide traceability from each system requirement in this specification to the top-level system requirement it addresses, including traceability through any intervening specifications; and from each top-level system requirement allocated to this system to all system requirements that address it.*

SYSTEM SPECIFICATION (con't)

INTERFACE REQUIREMENTS.

GOVERNMENT FURNISHED PROPERTY INTERFACES. *List interface characteristics for all entities of government property to be incorporated into the system.*

EXTERNAL INTERFACE REQUIREMENTS. *In separate subparagraphs, list external interfaces of the system. If external services are used, include their interfaces.*

INTERFACE NAME. *Identify each external interface by name (and, for software, project unique identifier) and list the entities making up that interface.*

Computer Hardware Requirements. *State requirements for computer hardware that must be used by, or incorporated into, the system. Examples include number of each type of equipment, type, size, capacity, and other required characteristics of processors, memory, input/output devices, auxiliary storage, communications/network equipment, and other related equipment.*

Computer Communications Requirements. *State requirements concerning the computer communications that must be used by the system. Examples include geographic locations to be linked; configuration and network topology; transmission techniques; data transfer rates; gateways, required system use times; type and volume of data to be exchanged; time boundaries for transmission/reception/response; peak volumes of data; and diagnostic features.*

Computer Software Requirements. *State requirements regarding computer software that must be used by the system. Examples include operating systems, database management systems, communications/network software, utility software, input and equipment simulators, test software, and manufactured software.*

PRECEDENCE AND CRITICALITY OF REQUIREMENTS. *Specify the order of precedence, critically, or assigned weights indicating the relative importance of the requirements in this specification. Examples include identifying requirements deemed critical to safety, to security, or to privacy for purposes of singling them out for special treatment. If all requirements have equal weight, this paragraph should so state.*

4. **VERIFICATION.** *State all verifications to be performed to determine that the system to be offered for acceptance confirms to all requirements in Section 3 above. Do not include quality assurance provisions that belong in the contract, such as responsibility for inspection, establishment of quality or inspection program requirements, warranties, instructions for nonconforming items, and contractor liability for non-conformance.*

METHODS OF VERIFICATION. *State methods which may be used to verify compliance with the requirements of Section 3 above. Examples include analysis, demonstration, examination, test.*

DESIGN VERIFICATION. *For a performance specification, reference the portion of the cross-reference matrix specifying the requirements of Section 3 that are the basis for design verification, the inspection methods to be used, and the specific Section 4 inspections to be used to verify the requirements. Also define any requirements relating to mandatory sequence of inspections, number of units to be inspected, data to be recorded, and the criteria for determining conformance to the design verification requirements.*

INSPECTIONS.

SYSTEM SPECIFICATION (con't)

GENERAL INSPECTION REQUIREMENTS.

INSPECTION CONDITIONS. *Identify the environmental conditions under which all inspections of production items are to be performed.*

INSPECTION EQUIPMENT. *Identify the inspection equipment required to perform the specified inspections and relate the equipment to each inspection characteristic, as appropriate.*

DETAILED INSPECTION REQUIREMENTS. *Include a separate subparagraph for each inspection to be performed on the system.*

DETAILED INSPECTION ELEMENT (NAME).

Methods of Inspection. *Describe the inspection to be performed including inspection method, location and number of inspections, inspection routine, and criteria for determining conformance.*

Special Inspection Conditions. *Specify any special environmental conditions under which this inspection is to be performed.*

Special Inspection Equipment. *Include requirements relating to the adequacy of the inspection equipment.*

5. PACKAGING. *If packaging required, state: "For acquisition purposes, the packaging requirements shall be as specified in the contract or order."; if packaging not required, state: "N/A".*

6. NOTES. *This section should only contain information of a general or explanatory nature, designed to assist in determining the applicability of the specification and such other information as deemed appropriate. Examples are: intended use, special requirements to be incorporated in any contract that cites this specification, list of acronyms and abbreviations, impact on international standardization agreements. The information in this section is not binding unless it is specifically referenced in Sections 3 or 4.*

APPENDIXES. *Appendixes may be used to append multi-page data tables, a specification tree, classified information, or other information that would normally be included in the specification but would, by its bulk or content, tend to degrade the use of the specification. When appendixes are used, they should be referenced in Section 3 or 4 as appropriate.*

APPENDIX B. SYSTEM ENGINEERING MANAGEMENT PLAN

The systems engineering process is applied iteratively throughout the system life cycle to translate stated problems into design requirements, providing an integrated system solution consisting of people, products, and processes with the capability to meet user needs. The systems engineering process is defined in EIA Standard 632.

This standard defines a total system approach for the development of new systems. It provides the foundation for integrating product and process development. This requires: the simultaneous development of a system products and life-cycle processes to satisfy user needs; multidisciplinary teamwork; and a system engineering approach. A System Engineering Management Plan (SEMP) describes the application of this standard for a particular technical effort. The intended use of the SEMP is to coordinate and integrate all applicable plans and planning, by developing and formalizing the SEMP prior to system engineering process execution, using the SEMP in executing the effort, and maintaining the SEMP for the duration of the effort. The SEMP is structured to facilitate its application contractually in lieu of this standard.

The SEMP defines the performing activity's plan for the conduct and management of a fully integrated technical effort. It represents the agreed-to-tailoring of standardized/generic systems engineering descriptions to accomplish technical requirements. The SEMP is used by tasking activity to evaluate the performing activity's technical approach, to make technical risk assessments, and to gauge progress. It is used by the performing activity to manage and integrate the full spectrum of technical activities.

The requirements of a SEMP are outlined on the following four pages. This outline is adapted from EIA Interim Standard 632 [Ref. 12].

SYSTEM ENGINEERING MANAGEMENT PLAN

1. **SCOPE.** Give a brief description of the purpose of the system to which this document applies and a summary of the purpose and intent of this document. Include an summary description of how the technical activities covered in other plans are accomplished as fully integrated parts of the technical effort.

2. **APPLIABLE DOCUMENTS.** List the documents applicable to implementation of this plan.

3. **SYSTEM ENGINEERING PROCESS.**

SYSTEMS ENGINEERING PROCESS PLANNING. Address key program technical objectives, products, and expected results from the process, needed process inputs, and work breakdown structure development.

MAJOR PRODUCTS AND RESULTS OF THE PROCESS. Describe major products and results of the documented system engineering activities. Examples are: Integrated Decision Data Base, Specifications, and Configuration Baselines.

PROCESS INPUTS. Explain depth of information detail needed to accomplish these system engineering activities, how that information will be acquired, and how conflicts in information will be resolved.

TECHNICAL OBJECTIVES. Describe technical objectives and their relation to cost, schedule, performance, and risk.

WORK BREAKDOWN STRUCTURE. Describe work breakdown structure development and how it will relate to planning packages and work packages.

TRAINING. Describe the method for providing training for performing and tasking activities.

STANDARDS AND PROCEDURES. Describe standardization documents and procedures that the program will follow.

RESOURCE ALLOCATION. Describe the technical basis and rationale for resource allocation to program technical tasks.

CONSTRAINTS. Describe limitations or restrictions the program will observe in areas of funding, personnel, facilities, manufacturing capability, and critical resources.

WORK AUTHORIZATION. Describe method by which work packages will be opened, closed, and changed.

VERIFICATION PLANNING. Describe verification planning for all requirements. Include identification and configuration control of verification tools.

SUBCONTRACTOR/SUPPLIER TECHNICAL EFFORT. Describe level of subcontractor participation in the technical effort and the systems engineering role in subcontractor/supplier selection and control.

SYSTEM ENGINEERING MANAGEMENT PLAN (con't)

REQUIREMENTS ANALYSIS. *Describe the methods, procedures, and tools for analysis of missions/operations and environments; identification of functional and performance requirements for development, manufacturing, verification, deployment, operations, support, training, and disposal; and determination of constraints in the areas listed below.*

RELIABILITY AND MAINTAINABILITY.

SURVIVABILITY.

ELECTROMAGNETIC COMPATABILITY, RADIO FREQUENCY MANAGEMENT, AND ELECTROSTATIC DISCHARGE.

HUMAN ENGINEERING AND HUMAN SYSTEMS INTEGRATION.

SAFETY AND HEALTH HAZARDS.

PRODUCABILITY.

PRODUCT SUPPORT (INCLUDING SUPPORTABILITY).

TEST AND EVALUATION.

INTEGRATED DIAGNOSTICS.

TRANSPORTABILITY.

INFRASTRUCTURE SUPPORT.

OTHER AREAS OF SYSTEM FUNCTIONALITY.

SYSTEM ENGINEERING MANAGEMENT PLAN (con't)

FUNCTIONAL ANALYSIS/ALLOCATION. Describe the approach, methods, procedures, and tools to perform functional analysis/allocation. Include a discussion on integrating factor-dependent approaches and methods for the area tasks listed above under requirements analysis.

SYNTHESIS. Describe the approach, methods, procedures, and tools to perform synthesis. Include a discussion on integrating into synthesis factor-dependent approaches and methods for the area tasks listed above under requirements analysis, and the use of levered options such as commercial-off-the-shelf, non-developmental-items, open systems architecture, re-use, and commercial/government-use technologies.

SYSTEMS ANALYSIS AND CONTROL. Describe the approach, methods, procedures, and tools to be utilized for system analysis and control. Include a discussion on integrating into synthesis factor-dependent approaches and methods for the area tasks listed above under requirements analysis.

SYSTEMS ANALYSIS. Describe the specific systems analysis efforts needed for trade studies, system and cost effectiveness analysis, and risk management. Include methods, procedures, source data, and tools necessary for their conduct.

CONTROL. Describe the specific control mechanisms needed for configuration management, interface management, data management, systems engineering master schedule, technical performance measurement, technical reviews, subcontractor/supplier control, and requirements tracability. Include methods, procedures, and tools necessary for their conduct.

4. TRANSITIONING CRITICAL TECHNOLOGIES. Describe the activities, associated risks, and criteria for assessing and transitioning technologies, including those for transitioning critical technologies from technology development and demonstration programs. Also describe the planned method for engineering and technical progress improvement including procedures for establishing preplanned product improvement or evolutionary development, as pertinent to the life-cycle phase.

5. INTEGRATION OF THE SYSTEM ENGINEERING EFFORT. Describe how the various inputs will be integrated into a coordinated systems engineering effort meeting cost, schedule, and performance objectives; how the performing activity will organizationally support the systems engineering effort; major responsibilities and authority for conducting systems engineering efforts; planned personnel needs by discipline and level of expertise; and use of methods to support design integration.

6. IMPLEMENTATION TASKS. Describe required implementation tasks including: technology verifications, process proofing, manufacturing of engineering test articles, development test and evaluation, generation and re-use of software for system end-items, and sustaining engineering and problem solution support.

SYSTEM ENGINEERING MANAGEMENT PLAN (con't)

7. ADDITIONAL SYSTEMS ENGINEERING ACTIVITIES.

LONG-LEAD ITEMS. *Describe the process by which long-lead items that affect the critical path of the program are defined/determined.*

ENGINEERING TOOLS. *In individual subparagraphs describe how the named tools (and any other tools) will be used on the program as well as the reliance on them and control of them.*

ANALYSIS TOOLS.

SYNTHESIS TOOLS.

CONTROL TOOLS.

REFERENCE TOOLS.

SIMULATION TOOLS.

LABORATORY AND OTHER FACILITY TOOLS.

DESIGN TO COST. *Describe design to cost requirements with emphasis on how they are allocated as well how compliance is determined and controlled.*

VALUE ENGINEERING. *Describe the value engineering effort and how it will be implemented and administered.*

SYSTEM INTEGRATION. *Describe the approach for integration and assemble of the system with emphasis on risk management and continuing verification of internal and external interfaces.*

OTHER METHODS AND CONTROLS. *Describe any other methods and controls that will be used in the technical effort.*

8. NOTES. *Include any general information that aids in understanding this system engineering management plan (e.g., background information, glossary) and an alphabetical listing of all acronyms and abbreviations, with meanings as used in this document.document*

APPENDIXES.

TECHNICAL PERFORMANCE MEASUREMENT.

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