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Engineering Management Technology Transfer in Naval Engineering Curricula

Robert H. Mayer
United States Naval Academy

Abstract

This paper will describe new project management opportunities within the ocean engineering and naval architecture programs at the U.S. Naval Academy. Specifically, engineering management skills and techniques have been adapted to naval engineering settings and included in a new project management area of concentration.

One elective course, in particular, introduces students to various inventory, queuing, linear programming and decision theory models, using a conventional management science textbook supplemented by applications from the marine environ. Examples include optimum dredging strategies for navigation channel maintenance, beach fill operations for shore protection and recreational planning, port development and commercial ship routings. Application of such skills crosses many naval disciplines including fleet operations and logistics, engineering duty officer and staff corps responsibilities. The goal of this course is to enhance the engineering and project management skills of Academy midshipmen. Practically speaking, enhancement of such skills will benefit all future naval officers and engineers.

Details of the initial offering of this engineering management course as well as other project management opportunities at the U.S. Naval Academy will be reviewed. Suggestions will be offered for further project management developments in ocean engineering and naval architecture programs at this and other institutions.

Introduction

The three principal oceans and their adjoining seas cover more than 2/3 of the earth’s surface and serve as vast storehouses of ocean resources including food, minerals, building materials, fossil fuels, renewable energies and fresh water through desalination. Given such a valuable source of supplies, it seems odd that few textbooks and but a relatively few reference books address the effective management of our ocean resources. Even the conventional textbooks used in engineering and engineering management courses reflect few references to ocean applications.

To account for this opportunity in ocean resource management, a new curriculum is evolving within the ocean engineering major at the U.S. Naval Academy (USNA). With existing elective tracks in Civil and Coastal Engineering, Deep Ocean Technology, and Ocean Environmental Engineering, the faculty has initiated a newer thrust in ocean engineering Project Management. At the core of this discipline are four related courses: EN412 – Ocean Resources Engineering; EN445 – Marine Fabrication Methods; EN450 – Engineering Economic Analysis; and,
EN486A – Project Management for Naval Architects and Ocean Engineers. Details of EN412 and EN445 were described in earlier papers published in these proceedings [1, 2]. EN450 is a traditional course taught with a conventional text, most recently [3], that is supplemental with sample problems and homework dealing with ocean engineering applications. EN486A was developed by the author and taught for the first time in spring semester 2003 using a conventional management science textbook [4]. Students are initially introduced to various inventory, queuing, linear programming and decision theory models through generic textbook problems – most with a business management context. However, since the goal of this course is to enhance the engineering and project management skills of Academy midshipmen – specifically those majoring in naval architecture and ocean engineering - many of the problem solving techniques have been adapted and applied to projects and applications typically encountered in a marine environ.

Details of the initial offering of the project management course are reviewed. However, the principal focus of this paper is the selected project applications and techniques used to facilitate the technology transfer from engineering management in a business sense to that encountered in the ocean realm. Suggestions are also offered for further project management developments in ocean engineering and naval architecture programs at this and other institutions.

Project Management at USNA – an initial course offering

The ocean engineering curriculum at the U.S. Naval Academy is a four-year undergraduate, ABET-accredited program specializing in civil and coastal engineering, deep ocean technology, ocean environmental engineering and, more recently, ocean engineering project management. Within the curriculum structure, students are able to select four elective courses from one or more of the four track programs. That is, they may specialize in one focus area of ocean engineering or gain a broader base of knowledge from the various tracks.

The newest of elective courses is EN486A: Project Management for Naval Architects and Ocean Engineers. The initial offering of this course was in the spring of 2003. Course enrollment was small – 10 students majoring in either ocean engineering or naval architecture. The text, Quantitative Analysis for Management [4], was chosen as much for its supportive web site as for its content. The course was principally lectured based, with various web-site power point applications revised to reflect a greater emphasis on marine applications. Topics were introduced in much the same order as the text and included probability, decision theory, forecasting, inventory models, linear programming, CPM and queuing theory. Homework was assigned both from the chapter sets as well as problems developed by the instructor. Weekly quizzes were web-based with immediate feedback available on-line. However, most significant of course developments was the adaptation of the solution techniques from the traditional business management context to ocean resource management applications. Examples follow in the next section.

EM Technology Transfer to the marine environ

- Linear Programming. Examples of some basic engineering management applications in the marine environ can be found in an earlier paper by Mayer and Stark [5]. Unit-price contract
bidding strategies and allocation strategies for borrow and disposal of dredge material were formulated and sample problems solved using linear programming.

As another example, the conventional fluid blending problem of linear programming is conveniently adapted to blend borrow sands to meet beach fill requirements. Whenever there is flexibility in the specifications, a linear programming formulation can readily provide the most cost-effective borrow combinations [6].

- **Network Models.** The success of the fishing industry is very much dependent on its ability to effectively manage its human, financial, and physical resources while maintaining the viability of its fishing stocks. As suggested in Figure 1, conventional network models have been formulated [7, 8] to address the problem of dispatching trawler fleets to fisheries to meet demand requirements (for fish stock) under various vessel constraints and fish catch limitations. Similar models can be developed for most commerce applications involving sea transport. Of course, while solvable by various network flow techniques, these same models can also be conveniently formulated and solved using linear programming.

![Network flow model for trawler fleet routings](image)

*Figure 1. Network flow model for trawler fleet routings*

The well-known critical path method (CPM) is another network model that calls for optimum scheduling of project activities with various sequential relationships. Adopted in many industries to determine least time and least cost schedules, CPM is a useful tool for effective scheduling of ocean-related construction and shipbuilding projects. Once more, such problems are readily formulated and solved by linear programming [6].

- **Inventory Models.** An objective of the economic lot size model is to define an inventory management policy of minimum cost. As suggested by the parameters “Q” and “t” in Figure 2, the inventory manager is interested in determining “How much?” and “When?” certain stocked material should be replenished. In general, the optimal inventory level is dependent on customer demand, while the costs of producing and holding inventory are balanced off against one another. The cost impact of inventory shortfalls (shortages) adds a further degree of complexity to the model.
The manager of a beach re-nourishment project might utilize the economic lot size model to determine an optimal quantity of sand to place on an eroding shoreline and the time interval between such replenishments. The inventory in question would be the quantity of beach sands and “customer demand” would be reflected by the erosion rate of the shoreline. Since the presence of adequate beach sands provides both recreational benefits and protection to back-shore properties, shortages of inventory (in this case, sand) can have disastrous consequences in both economic and structural terms. Thus, the loss of recreational opportunities and the potential damage costs to beach front properties must be incorporated in the model’s objective function. A recent student research project seems to suggest that so long as production costs are linear and demand constant, the greater the sand inventory the better [9]. Of course, more realistic models should address non-linear costs, variable (and uncertain) erosion rates, and the aesthetic and practical dis-benefits of excessively high beach dunes.

Alternatively, a decision maker responsible for maintenance of our nation’s waterways might require answers to “When?” and “To what depth?” a channel should be dredged. Impacts associated with these decisions include the cost of dredging and the efficiency and safety of navigation. If channel sediments are viewed as inventory, then channel maintenance is somewhat akin to inventory management except that the maintenance manager would prefer to deplete, rather than stock, inventory. Unfortunately for management, rather than be diminished, sediment inventories are readily (and freely) supplied by the natural environment, e.g., Figure 3.
depth seems cost effective for both economizing dredge costs and improving navigation efficiencies [10].

- Queuing Models. Queuing or waiting line models seek the optimal design of service facilities. In a marine context, container or bulk-cargo ships arrive at ports seeking offload and loading services at often limited berthing facilities. Optimal service should reflect a proper balance between the cost of providing service (either in terms of the number of berths or the efficiency of operations) and the cost of ship demurrage both while awaiting berthing and during load/offload operations. The combined cost of operations is reflected in Figure 4. Such methods of analysis may be useful in deciding whether to expand or upgrade port service facilities [11].

![Figure 4. Competing cost curves for port operations](image)

These and other models have been included in the new course EN486A to enhance student understanding of the solution techniques while gaining appreciation of their application in the students’ career field of choice. While the comprehensive nature of the course was challenging to the students who enrolled in the initial offering of this “Project Management” course, the feedback through class discussions and course evaluations has been encouraging.

Alternative courses in Project Management at USNA

As noted previously, three other track electives for the project management are EN412, EN450 and EN445. Brief descriptions of each follow.

- EN412, Ocean Resources Engineering: The principle focus of this course is the identification, recovery, and utilization – i.e., effective management – of ocean resources including alternate energy sources; deep-ocean oil and gas recovery; desalinization; uses for dredge spoil; mineral exploitation; wetlands, reefs and other coastal developments; along with related discussions of environmental economics, ethics, and regulatory statutes. Currently, this is the most popular of engineering elective courses with a Spring Semester ’04 enrollment of 59 midshipmen.

- EN445, Marine Fabrication Methods: This course presents some of the basic techniques used to fabricate offshore structures and ships. Understanding of metal, concrete, and composite
construction and quality control methods is stressed. An understanding of fabrication specifications is also developed through group projects in each material category.

- **EN450, Engineering Economic Analysis:** Basic methods and reasons for conducting an engineering economic study are presented. Economic criteria are developed and procedures for selecting from among a set of technically feasible alternatives are studied. When appropriate, ocean engineering and naval architecture applications are introduced.

In a parallel effort, the Weapons and Systems Engineering Department of USNA has initiated a new track in engineering management. The focal point of their efforts lies in its two fundamental courses:

- **ES485E:** Engineering Management I: This course provides a general introduction to Operations Research and its application to engineering. Topics include optimization of engineering systems, game theory, sensitivity analysis, project management with PERT/CPM, and Decision Analysis.

- **ES486E:** Engineering Management II. This course focuses on the implications of advanced technologies from a global, societal and financial perspective. Topics include an analysis of past technologies, and investigations into new technologies such as nanotech and human genetic engineering.

Further details of both the project management track in Ocean Engineering and the engineering management track in Weapons and System Engineering can be found on the USNA web site: [http://usna.edu/](http://usna.edu/). More recently, faculty of these two programs and those of Naval Architecture have been exploring the possible development of an Engineering Management major at USNA. Discussions are preliminary, but enthusiasm among the participants is high.

**Conclusion**

The ultimate goal of the new project management track in ocean engineering is to enhance the engineering and project management skills of all Academy midshipmen. Application of such skills crosses many naval disciplines including engineering duty officer, fleet operations and logistics, and staff corps responsibilities. Practically speaking, enhancement of such skills will benefit all future naval officers.

More directly, the project management track in ocean engineering will serve not only to enhance the management skills of our graduates as naval officers but also provide managerial insights into engineering decisions in their chosen major. While course instructors in each of the four track electives have been challenged to adapt traditional engineering management problems to marine applications, the benefits to our students is realized through increased comprehension of the material and a sincere appreciation of the instructors’ efforts.

Of particular interest to the faculty is the continued development of the EN486A elective course. We are continually alert to new applications of engineering management technology in the marine environ. Our students are encouraged to pursue research papers and independent
research projects on related topics; such was the case in the development of reference [9]. It is a personal goal of this author to eventually produce a brief manuscript which consolidates many applications of the type noted in this paper such that instructors at other institutions can readily adapt a conventional engineering management text to the ocean engineering discipline. Contributions from readers will be greatly appreciated.

Bibliography


Biographical Information

ROBERT H. MAYER
Professor Mayer is a past Program Director of Ocean Engineering at USNA. He teaches courses in engineering design, economic decision making, and marine-related environmental engineering. Research interests relate to the application of statistics and operations research methods to the management, engineering and construction of ocean facilities. He previously served in the Civil Engineer Corps, USN, as an ocean engineer and diving officer. E-mail: mayer@usna.edu.