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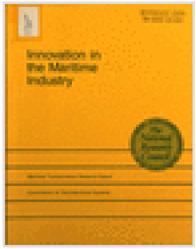

Innovation in the Maritime Industry (1979)

Maritime Transportation Research Board; Commission on Sociotechnical Systems; National Research Council

Pages
111

Size
8.5 x 10

ISBN
0309332737

Innovation in the Maritime Industry

Committee on Innovation and Technology Transfer in the Maritime Industry

MARITIME TRANSPORTATION RESEARCH BOARD
COMMISSION ON SOCIOTECHNICAL SYSTEMS
NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C. 1979

NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

* * * * * *

This is a report of work supported by the Departments of Commerce, Defense, and Transportation under provisions of Contract N00014-75-C-0711 between the National Academy of Sciences and the Office of Naval Research.

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Printed in the United States of America

FOREWORD

This study was made under the auspices of the Maritime Transportation Research Board (MTRB) of the National Research Council as a part of a continuing program of advice to the federal government directed toward improving maritime and maritime-related transportation. The study was undertaken at the request of MTRB's sponsors.

The process of identifying and adopting innovations is a subject that affects all sectors of the maritime industry. Accordingly, an interdisciplinary committee was formed to address the problem. The areas of competence represented on the committee include naval architecture, economic geography, technology transfer, distribution and transportation planning, economics, labor relations, marketing, and engineering management. Edward M. MacCutcheon, a consultant and the former Chief of the Office of Research and Development of the Maritime Administration, served as committee chairman.

I extend my thanks to the committee chairman and members, liaison representatives, and project manager for their fine work on this report. My thanks also go to the review committee for its efforts on behalf of the Board.

R. R. O'Neill
Chairman
Maritime Transportation Research Board

Washington, D.C.
October 1979

PREFACE

In a country built by innovative risk-takers, the current depressed state of the U.S. maritime industry is an issue of great concern. Following World War II, U.S.-flag vessels carried nearly 58 percent of all U.S. oceanborne commerce. Since that time, there has been a steady decline in that percentage, and, in fact, within the last year two large U.S.-flag shipping companies have experienced such financial difficulties that they have ceased doing business.

As one approach to finding some answers to this problem, the Maritime Transportation Research Board convened a committee to look at innovation in the maritime industry and to recommend ways to improve the climate for innovation.

As the committee began the study, we faced a variety of questions. Is the U.S. maritime industry really as conservative and inflexible as some people feel? Are foreign maritime industries really more innovative? How does one measure innovation? What, in fact, is the true nature of the U.S. maritime industry?

The committee quickly found or invented definitions, formulated hypotheses, and selected a positive plan for action. We tried to choose a route that started with recognized principles, pursued directions guided by our idealism, and finally led to practical, achievable recommendations.

We agreed that America should have a maritime industry commensurate with the importance of its trade, and that, in the past, innovation has been an important factor in the growth and maintenance of that industry. However, in recent years, other techniques, including the buying of added strength through direct government subsidies, have been used. Most of these have offered an immediate, measurable stability. However, they are short-term solutions and cannot ensure continued health in such a highly competitive industry. We have attempted to define the long-term advantages of innovation and to formulate recommendations that will increase maritime innovation and improve the competitive position of the U.S. maritime industry.

The members of the committee have contributed much personal time to the development of this report. Our Project Manager, Marlene R.B. Phillips, and our editor, Linda L. Jenstrom, worked diligently to combine diverse committee styles into a single document.

We are grateful for the opportunity to learn from each other and to promulgate some thoughts that we hope will increase the strength of the U.S. maritime industry.

E.M. MacCutcheon

Edward M. MacCutcheon
Chairman
Committee on Innovation and
Technology Transfer in the
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Washington, D.C.
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ACKNOWLEDGEMENTS

A number of highly qualified people have aided the committee in its efforts to address innovation in the maritime industry. Some prepared case studies which appear in the Appendix of this report, others attended committee meetings and made presentations on their work and experience, and still others contributed by submitting written descriptions of their work and experiences. Though the thoughts of all are not always specifically identified in the text, each will recognize the flavor and content of his contribution throughout the report. We thank each for his valuable contribution.

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APPENDIX
(Published as separate volume)

Innovation in the Maritime Industry

EXECUTIVE SUMMARY

BACKGROUND AND PURPOSE

The U.S. maritime industry serves the nation in many ways including bolstering national defense, providing transportation services, and improving the national economic well-being. Continued accomplishment of these functions requires a strong industry, capable of meeting competition not only from the maritime industries of other nations, but also from other forms of transportation such as air transport and pipelines. If the U.S. maritime industry is to compete successfully, it must continue to increase its capacity to innovate.

In February 1977, the Maritime Transportation Research Board (MTRB) of the National Research Council formed a committee to address the subject of innovation and the innovation process within the maritime industry. Committee members knowledgeable in a number of areas, including naval architecture, transportation and distribution, ship operation, labor relations, information exchange, and economics, were selected to consider the factors that influence the U.S. maritime industry's ability to innovate and to recommend actions that would improve the climate for innovation within the industry.

APPROACH

Early discussions within the committee convinced members that innovation is useful and essential to the growth of all forms of commerce, including the maritime industry. Accordingly, the committee established the following objective: to find ways to increase the generation and adoption of innovations that will help the U.S. maritime industry better serve its purposes in continued consonance with the socioeconomic values of the nation. To accomplish the study objective, the committee surveyed current literature, talked with innovators and people involved in the innovation process, and examined examples of maritime innovations to determine what factors acted as either incentives or deterrents to the process and what changes could be made to improve the climate for generating, transferring, and absorbing new technology and new practices. The committee examined the progress of specific hardware and software innovations, as well as the total process of innovation within the industry. They found that the process of innovation consists of four basic stages -- recognition and selection, planning and development, implementation, and diffusion. To some extent, each of these stages is applicable to all innovations studied. Case studies developed for committee deliberation are included in the Appendix of this report.

CONCLUSIONS AND RECOMMENDATIONS

Three basic industry groupings comprising a complex of organizations make up the U.S. oceangoing maritime industry. The differences among these groupings -- ship operation, shipbuilding, and port operation -- made the analysis of problems and the development of conclusions and recommendations more difficult.

The following is a summary of the committee conclusions and recommendations. The full text of the conclusions appears at the end of each chapter, and the recommendations are contained in Chapter VII. The conclusions and recommendations resulting from this study are grouped in four areas -- finance and economics, people and institutions, research and development, and information and education.

Finance and Economics

In general, the profit potential dominates the planning goals of industry decision makers. In some cases, dire necessity and the threat of economic disaster have been the motivating factors that have caused industry members to innovate. At other times, the opportunity for high profits has been perceived as outweighing the risk of innovation failure. Both of these cases provide a strong, positive influence to the speedy adoption of innovations.

On the other hand, the limited size and relatively low return on investment characteristic of the various segments of the industry make them uneconomical markets for suppliers and reduce the industry's ability to attract risk capital. The cyclical nature of the business and the use of direct subsidies, as well as the time requirements for the promulgation of regulations and the U.S. tax structure, reduce the industry's ability to innovate. The high cost of ships makes them poor subjects for experiments, and a possibility of innovation failure will affect the insurance rates. The committee recommended several changes to help improve the industry position.

- Promote industry-government cooperation in exploring a variety of indirect subsidy and/or tax benefit arrangements to stimulate industry-wide innovation.

- Develop insurance programs to insure against loss of operating revenue during innovation trials or shakedown periods, thus increasing industry's willingness to accept the high costs and high risks of innovating.

- Demonstrate the application of research results through the periodic building of innovative merchant ships to government account. Such ships would be suitable for resale or charter to U.S.-flag operators.

- Undertake the testing and adoption of innovations on government-operated ships, thereby having government share in the risk associated with system failure.

- Explore additional government-industry cost-sharing and/or loan-financing to underwrite innovations and defray the introduction costs associated with innovation.

- Examine the appropriateness of special tax credits for innovators and modify the current depreciation allowance structure aimed at recovery at current or replacement value.

- Increase the flexibility in the designated periods of cost recovery and retained profits for domestic operators to allow more timely allocation of the benefits of successful innovation to the innovators.

People and Institutions

A lack of awareness and/or a lack of accurate and timely information about the uses and benefits of new technologies often acts as a barrier to innovation. Alternatively, informed flexible, effective managers within any company can operate as a stimulus to innovation. Better educated engineers and managers as well as a corporate recognition of the need to develop innovative capacity and responsibility will improve the ease with which companies adopt innovations.

The relationship between labor and management has a significant effect on the speed and effectiveness with which innovations are adopted. The two groups can improve the climate for innovation through cooperation in the transition phases of the introduction of new technologies and techniques. Committee recommendations in the area of people and institutions are

- Develop better management-labor cooperation in providing improved employment opportunities and training and retraining programs to smooth innovation transitions.

- Recognize the human costs of adjustment to new technology as a part of the cost of installation, thereby assuring equitable job and income security for affected workers.

- Increase the number of government-industry cooperative programs in all areas of maritime transportation to improve the recognition and adoption of innovations.

- Undertake periodic policy reviews of federal constraints on the introduction of new technology and modify or remove those constraints found to be unnecessary.

Research and Development

Most new technology results from successful research and development projects. Even technologies borrowed by the maritime industry, whether from different nations or different industries, have required engineering development to complete the adoption process. Valuable research is being conducted at government and private research institutions, and government-industry cost-sharing programs have had a high success rate. Yet, with the possible exception of shipbuilding, investment in maritime industry research and development is sorely inadequate, and many U.S. inventions are developed overseas and returned to the U.S. under leasing or royalty arrangements. Several changes are recommended to increase support of U.S. maritime research.

- Increase research and development spending in both industry and government to increase the identification and development of maritime innovations.

- Establish priorities for federally funded maritime research and development through expanded industry-government dialogue.

- Allocate a larger share of federal research funds to basic R&D to develop the fundamental technology necessary for the industry.

- Allocate additional funds to support research to improve methods of adopting, implementing, and embedding new technologies to increase the identification and development of maritime innovations.

Information and Education

The rate of innovation in the U.S. maritime industry is dependent, in part, on the rate and quality of information exchange and dissemination. The development of functioning information exchange systems is necessary for effective problem solving through information exchange and identification of potentially transferable technology.

Even more basic is a recognition of the need to use new technology and diverse sources of information. University programs and internal corporate information flow aid in the coupling of technology and market; however, engineers must still be educated as to the sources of available technology. The committee developed a number of recommendations aimed at improving the flow of information and the improvement of instruction dealing with information exchange.

- Increase the development in educational institutions of information transfer tools including seminars, workshops, and course work to further the professional development of students.

- Establish a center for exchange of maritime information to serve as a focal point for efforts to evaluate industry needs and stimulate technology transfer.

- Appoint people to serve as information liaison agents within individual companies to help the company become more effective and competitive.

- Appoint information liaison agents within trade associations to increase the flow of information about new technologies to potential users.

- Develop special industry-government programs aimed at increasing public awareness of the value of the commercial shipping industry.

INTRODUCTION

Advancing technology has been an integral element in the emergence of the United States as a world power and leader. Vigorous research and development during two world wars was followed by outstanding accomplishments in space.[124] (Superscript numbers refer to bibliographic entries contained in the report Appendix.) It has been estimated that technological innovation was responsible for 45 percent of the nation's economic growth between 1929 and 1969.[154] Not only do U.S. scientists and technologists accept technological advance as a way of life, but our leaders and our people share their faith in it. The layman's faith is a pragmatic recognition of the needs he has seen satisfied by new technology. Man has prospered by technological advance; organizations need it for survival; and it is an integral part of the American way. The continued growth of organizations, including nations, requires a continuing evolution in technology. Without technological advance, organizations risk obsolescence and replacement by competitors.

The purpose of the U.S. maritime industry is to be an arm of the national defense in the event of war, provide maritime transportation services for customers, generate profits and goal satisfaction for industry owners, improve the national economic well-being, and help provide for the security of the nation in peace and during foreign conflicts. The socioeconomic values of the United States require that these purposes be served with adequate attention to social equity, environmental protection, safety, and stewardship of resources.

The ocean transportation sector of the American maritime industry is involved in ongoing competition from two sources. The first, and more apparent, is competition from foreign carriers for the existing maritime trade. In 1966, the United States ranked sixth in the world in total number of trading vessels; in 1976, it ranked eleventh. The second source of competition is the development of alternatives to maritime transport. Alternatives include other forms of transportation, such as air transport and pipelines, as well as alternative manufacturing and distribution systems. Continued failure to meet this competition puts the oceangoing sector of the U.S. maritime industry in jeopardy of extinction.

If the U.S. maritime industry is to compete successfully, it must increase its capacity to innovate. It must evolve improved and/or lower cost services that can be offered at competitive rates. It is important to learn better ways to accomplish useful advances in maritime technology. Therefore, this study commences with the premise that effective innovation is useful and essential to the growth of all forms of commerce, including the maritime industry.

BACKGROUND

Over a span of several meetings, the Maritime Transportation Research Board (MTRB) of the National Research Council discussed two problems within the maritime industry: user demands and the lack of a flexible industry response to those demands, and the apparently slow pace of the absorption of new technology into the industry. The overlap of these two issues led to examination of a broader subject -- innovation.

In February 1977, the MTRB formed the Committee on Innovation and Technology Transfer in the Maritime Industry (see page vii for list of members) to study innovation with its broader issues, including such activities as research, development, invention, technology transfer, information exchange, and the diffusion and adoption of new things and methods. This report contains the results of the committee's study.

STUDY OBJECTIVE

As a committee, we defined our study objective as follows: to find ways to increase the generation and adoption of innovations that will help the U.S. maritime industry better serve its purposes in continued consonance with the socioeconomic values of the nation. To achieve the objective, we examined the innovation process in the industry and defined the manner in which the industry discovers, selects, and introduces technological advances. Finally, following the study, we formulated recommendations for ways to improve the climate for generating, transferring, and absorbing new things and new methods.

STUDY APPROACH

To accomplish the study objective, typical examples of the invention or development of ideas, activities, or hardware were examined. The process of transferring innovations from other industries or nations, as well as from company to company, was also explored. An attempt was made to determine how innovations are selected and how they are introduced and absorbed into the industry. Incentives and deterrents to the introduction of helpful innovations were studied and compared.

As we began our analysis of the innovation process in the maritime industry, our approach centered on the use of existing information, when possible, and the development of new material as necessary. Accordingly, an extensive review of published material dealing with innovation was conducted. Special abstracts of the literature were developed to facilitate comparison of the material in each book, report, and article. We also consulted with recognized innovators and other persons associated with technological change in the maritime industry, other industries, government, and academia. In many instances, these people made presentations to the committee.

As our work progressed, we found that new material was needed to fulfill the objectives of the study. Although the literature provided analytical studies of the many incentives and deterrents to the innovation process, there were too few studies specifically addressing the birth of innovations in the maritime industry. Therefore, we developed a series of case studies of innovations in the maritime industry. The following topics selected for study represent a broad cross section of industry components:

- Evolution of the Concept and Adoption of the Marine and Intermodal Container;
- A Federal Demonstration Project: N.S. SAVANNAH;
- The National Shipbuilding Research Program;
- Maritime Satellite Communications;
- The Innovation and Implementation of LASH (Lighter Aboard Ships);
- Port of Seattle Growth Through Modern Customer Services;
- Landbridge Services;
- Highly Skewed Propeller;

- Development of Gas Turbine Propulsion: the G.T.S. JOHN SERGEANT;
- History and Current State of Shipboard Automation;
- Contra-rotating Propulsion Systems for U.S.-Flag Merchant Ships;
- Hydrofoils in the U.S. Maritime Industry; and
- Air Cushion Vehicles.

Each case study provides background on a particular innovation. Many of the innovations studied are traced from inception to present standing in the United States, as well as the worldwide maritime industry. Emphasis is placed on the known or perceived factors that may have aided or inhibited progress, as well as on the interrelationships of these factors. All factors are described in the context of the economic, social, and regulatory conditions prevailing at the time the innovation was launched. Each case study attempts to quantify the influence the innovation has had on both the U.S. and foreign maritime industries.

While the factors represented in a specific case study will not necessarily prevail for all situations in the maritime field, the cross section presented by the case studies provided valuable insights into the process of innovation in the maritime industry. These case studies are included in the Appendix of this report.

In reviewing all of the assembled material, we found that the innovation process in the maritime industry is a vague set of activities that are complex in character, ambiguous in their effects, and difficult to describe. A large portion of our analysis was devoted to the identification of the process, its many diffuse elements, and the factors that influence and dictate the bounds of its behavior over time and organizations.

Influencing Factors

During our earliest meetings, we developed a list of nearly forty factors that may act as either an aid or an impediment to the development of an innovation. Among these factors were management, education, profits, economic necessity, patent laws, antitrust laws, and the public perception of the maritime industry.

We found, however, that a precise ranking of influencing factors was not possible. Some of the insights developed from the special interviews and case studies have revealed the dual character of some factors. A factor that is an incentive for innovation in one situation or at one time might be a deterrent to innovation in some other situation or time. In addition, a factor may simultaneously have both a positive and negative effect on the innovative process in different sectors of the industry. Identification of all of the relevant factors and a full assessment of all their effects proved particularly difficult. A second difficulty was the selection of a means for measuring the effects of the factors on the innovation process and the effects of the innovation on the industry. For example, factors that stimulate innovation do not necessarily enhance the U.S. maritime industry in relation to its international competitive position or its profits.

As a volunteer committee, we made no attempt to conduct detailed analyses of the factors. Our concern was to develop a realistic picture of the climate in which the industry functions. Extensive economic and/or policy analyses were beyond our time commitment.

The effect of any single influencing factor is a qualitative judgment derived from the experiences of maritime industry management, including owners, bankers, and key executives. In most cases, the management personnel we consulted expressed judgments on the effect of various influencing factors based on their experiences with particular innovations intended to improve the profit or competitive position of their companies. Many authors of the case studies attempted to reconstruct the judgments made by management and discover cause-and-effect relationships existing at the time policy decisions were made. The accuracy of the reconstructions in the case studies is, of course, dependent upon the quality of available documentation and the accuracy of the memory of those who were associated with the original decisions. A strong effort has been made to reconcile the information and to identify and illuminate the key factors that influenced the progress of the innovations described.

To simplify the discussion, the factors have been generally labeled as incentives or deterrents. The term incentive includes encouragements, helpers, inducements, motivations, opportunities, provocations, stimulants, and so on. The term deterrent includes barriers, constraints, hindrances, inhibitors, impediments, problems, prohibitions, restraints, and the like.

DEFINITION OF TERMS

According to Webster's dictionary, innovation is the act of innovating; i.e., the introduction of new things or methods. The word innovation commonly is also used to refer to something new that is introduced, whether it be a new piece of equipment, a new technique, or a new procedure.

However, we approached the term innovation on a broader level. Innovation is not synonomous with invention. Inventions are newly created products or techniques. In contrast, innovations may be existing concepts that are new to a given industry, enterprise, or application. Thus, an innovation adopted by the maritime industry could conceivably be some thing or method that the mining industry had used for decades. Secondly, innovation refers both to things or products and to techniques or methods. Thus, an innovation can be any new component, including changes in management procedures or personnel or changes to machinery (i.e., either hardware or software). A new bottom-welder, a new computer, a new computer program, a new supply order form, a new rotating-shift schedule, or the formation of a new development office within a company, can all be considered innovations.

Regardless of whether a given innovation is a new thing or a new method, we determined that the word "innovation" has two contents. The technological content of an innovation refers to the thing or method itself. The embedding content refers to the various adaptations that must be made by the host systems or organizations in order to embrace the new technology. Using shipboard automation as an example, the technological content of the innovation includes the computer-based hardware (i.e., the new mechanized equipment) as well as the software (i.e., computer programs and new procedures). The embedding content includes such factors as the new arrangements and adjustments required in staffing patterns, staff role definitions, and personnel training procedures, as well as new requirements for on-board living accommodations and working space.

Because the embedding content is less tangible and is harder to define than the technological content, all too often it is not given adequate attention. An example of failure to address the embedding content can be seen in the implementation of the LASH shipping concept. The first time that a LASH left Rotterdam, its barges contained tractors that had been manufactured and loaded on the barges in Germany and floated down the Rhine. By the time the ship made her trans-Atlantic crossing, most of the tractors were reduced to scrap metal. They had been secured sufficiently for transportation down the Rhine, since that was what the barge men knew how to do; however, the barge men had not been trained in the proper methods of securing tractors for an ocean crossing.[119] Clearly, it was not the technological content of the innovation, the LASH ship and barges, that was at fault. Rather, the failure lay in the embedding content, in the inadequate preparation given to the support system.

In the literature reviewed, we found the term innovation was often used rather loosely. Therefore, we made a distinction between any given act of innovation and the innovation process. The function of securing new things and methods and introducing them is called innovating; the act of doing this is innovation; the new things or methods that are put into place in host systems or organizations are innovations; and the sequence of typical activities undertaken when innovating is the innovation process.

ORGANIZATION OF THE REPORT

As our discussions, reading, and analysis progressed, it became obvious that the primary influencing factors fell into four larger areas. This report, therefore, proceeds from a general discussion of the innovation process, to a discussion of innovation in the maritime industry, to the factors affecting innovation in the industry, and, finally, to our committee recommendations.

Briefly, Chapter I describes the theoretical foundations considered useful in examining innovations and the innovation process. Drawing on theories developed in other fields, specific examples are given from the history of the U.S. maritime industry that clarify how intelligent planning can maximize the potential for success when introducing an innovation.

Chapter II contains an overview of the current status of the U.S. maritime industry, a brief overview of the role of innovation in the industry, as well as a review of a model program that demonstrates what has been done to improve the climate for technological change in one segment of the industry.

Chapters III through VI contain groupings of influencing factors we identified as incentives and/or deterrents to the innovation process. Chapter III discusses factors that are essentially external to the industry, including the public's perception of the industry and the effects of various government actions on the industry's propensity to innovate. Chapter IV discusses financial factors that affect the rate of technological change, including the economic motivations to innovate, availability of capital, and perceived risks of innovating. Chapter V presents a review of the key roles of people in the innovation process, including management, labor, and champions of innovation. Chapter VI discusses the relationship between industry and research and how that relationship might be improved.

The last section of each chapter contains a list of our conclusions. It should be noted that these conclusions may not cover all of the material and opinions presented. Rather, the conclusions carry the weight of committee consensus. In some instances, the text of sections of chapters of the report was supported by the majority of the committee, but dissenting opinions were held by a sufficient number of members to preclude adoption of a committee conclusion.

Chapter VII presents our recommendations. Each recommendation is derived from the conclusions and, therefore, carries the weight of committee consensus. It is hoped that adoption of the recommendations by industry and government will help facilitate the innovation process in the U.S. maritime industry.

The Appendix of this report has been published as a separate volume. It contains a number of case studies that were developed to aid us in our deliberations as well as the bibliographic list of reference materials used. The reference superscript numbers appearing in the text of the main report refer to this bibliography. We have included in the body of the bibliography the text of a series of abstracts developed by committee members during the course of this study. The abstracts address specific committee attention to deterrents and incentives to innovation.

CHAPTER I

THE PROCESS OF INNOVATION

A failure to adopt a proposed innovation or the failure of an innovation after adoption may be due to some basic defect in technical design; however, many failures are unrelated to the possible lack of merit of the design or to engineering inefficiency. After reviewing many examples of failed innovations, we concluded that problems associated with the acquisition of capital, the organization of the firm, management-labor relationships, maintenance or operating costs, market demand, or other ambient factors are more frequently the determinants of the success or failure of an innovation. For this reason, and because an understanding of the process may reveal ways to avoid some failures, it is important to examine the innovation process.

Basically, the process consists of several interlocking stages.[119] It begins with an initial recognition of a need or opportunity to innovate and concludes with the successful adoption, implementation, and diffusion of the innovation. The events that take place during each stage of the process govern whether or not a potentially effective innovation will be successfully adopted within a company or industry. The process does not occur in a vacuum. Rather, it is influenced and shaped by available and accessible technology, economic conditions, and the skills and interests of all personnel within the organization or industry.

There is no simple blueprint for the innovation process. Nevertheless, we found it helpful to examine the sequence of activities that commonly occurs when an institution, company, or industry innovates. Also, it was helpful to define stages in the innovation process. By analyzing the stages of the process, we found it possible to identify some basic characteristics that either expedited or impeded the adoption of specific innovations.

In the following discussion, we should note that the delineation of stages can be somewhat arbitrary, and each stage can be divided into a number of steps. We have arranged the stages in a crude chronological sequence;

however, it should be remembered that portions of adjacent stages may overlap, whole sections may be omitted, individual stages may be repeated, and recycling to earlier stages will sometimes be necessary.

Figure 1 is a simple schematic representation of the major stages and the sequence in which they commonly occur. The four major stages are

I. Recognition and Selection;

II. Planning and Development;

III. Implementation; and

IV. Diffusion

Presenting such a streamlined view of the innovation process can be a useful point of departure for discussion; however, the real-life process can be quite protracted. Substantial amounts of time can be consumed in realigning personnel, allocating the necessary economic resources, and developing and implementing the different kinds of activities that are needed to nourish each stage. Any of these factors -- the time involved, the resources needed, and the stage-appropriate activities required -- may be overlooked, and, as a result, a basically sound innovation may fail.

STAGE I: RECOGNITION AND SELECTION

The first stage of the innovation process, recognition and selection, begins with the recognition of either an opportunity to innovate or a need to innovate. Generally, an opportunity to innovate can be interpreted as a chance to surpass competition and to increase profits, while a need to innovate is often a dire economic situation or a need to match the opportunity-inspired move of the competition. Then, the specific innovation that best meets the need or exploits the opportunity must be selected.

Much of the theoretical literature that addresses the innovation process is oriented primarily toward problem-solving. Yet, an examination of the history of technological change in industry provides many illustrations of major innovations that have been adopted not because they provide a solution to an immediate, pressing economic or organizational problem, but rather because they promise the industry future growth, greater efficiency, more security, or other desirable returns. Examples of U.S. maritime innovations adopted because they represented new opportunities include LASH, containers, radio, the large

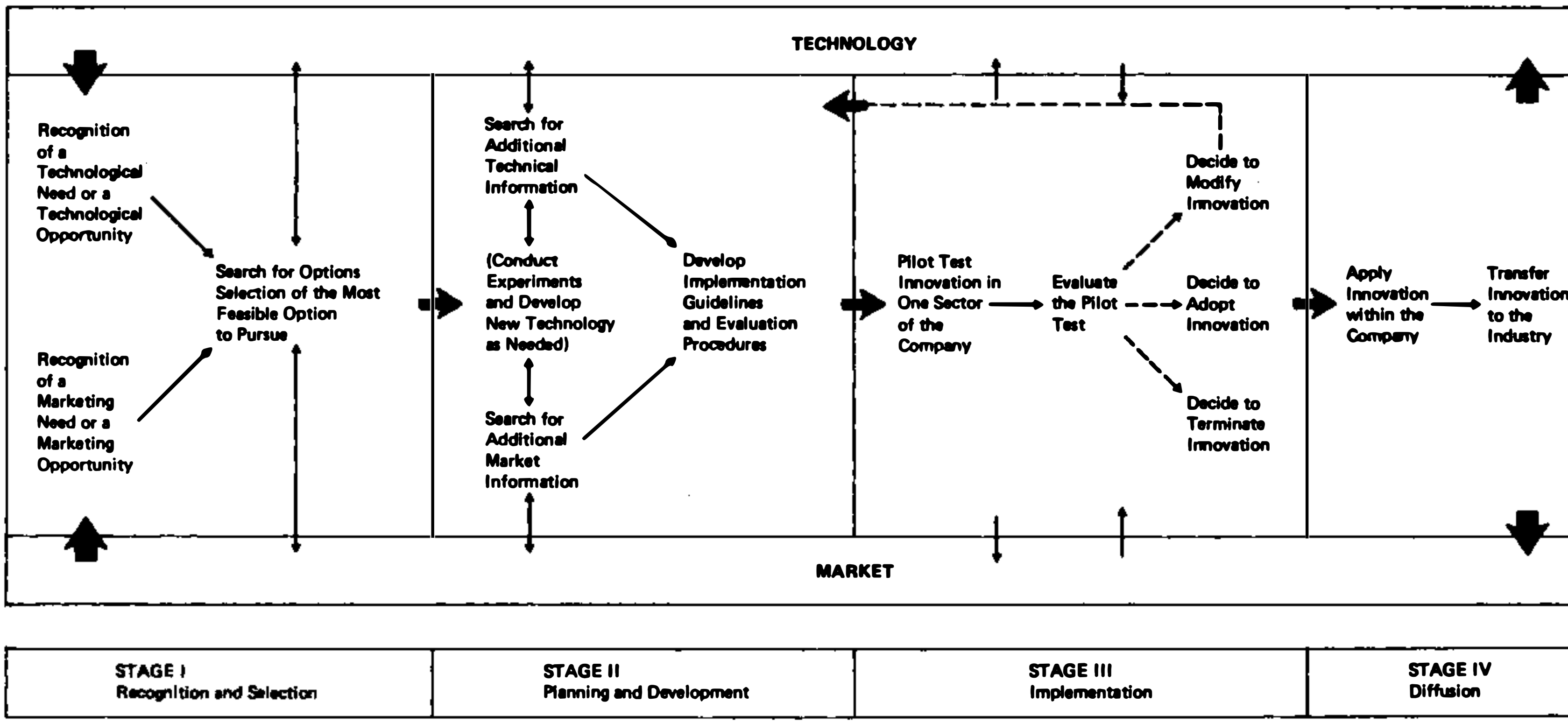

FIGURE 1 SCHEMATIC REPRESENTATION OF THE INNOVATION PROCESS

bulbous bow on slow speed ships, and the Marisat satellite system. (Of course, a successful innovation that is adopted in response to a perceived opportunity by one company or one sector of an industry may be adopted later by others as a means of remaining competitive.) Recognition that many innovations may be adopted because they offer an opportunity to improve productivity or service is critical to understanding the innovation process. If innovations are viewed only as a means of problem-solving, many potential improvements will be by-passed.

Of course, the innovation process is also used through recognition and selection to solve perceived problems. In general, perceived problems relate either to deficits or inadequacies of present technology or to changing market conditions. A perception of a need for new technology might arise from a demand for increased safety, more efficient engineering performance, or the reduction of an environmental hazard. Market conditions may generate a desire to improve the profit-loss ratio of a company or maintain a company's competitive position. If the innovation process is to continue to the next phase -- i.e., the search for a feasible solution -- the recognition of a technical or marketing need/opportunity must be coupled with a conviction that a feasible solution probably can be found.

In searching for a feasible solution to a recognized problem, or for the best means of exploiting a recognized opportunity, a number of alternatives must be investigated. These alternatives must be plausible in terms of existing economic, technical, and personnel resources. The number and type of alternatives considered will depend directly on the availability of venture capital, the interest of management in seeking changes, the quality of available labor, and the receptivity of labor to changes that may affect existing job specifications, as well as the user's or customer's perception of potential benefits.

Ideally, Stage I includes some, if not all, of the following steps:

- An opportunity or problem is recognized.
- A procedure or mechanism for assessing the problem or opportunity is either established or responsibility is assigned to an existing unit in a company or organization.
- The implications of the opportunity are assessed, or the causes of the problem or difficulty are diagnosed.

- A search is undertaken either for optional ways to take advantage of the opportunity or for potential solutions to the recognized problem.
- Several options are generated.
- Potential benefits and costs of each option are estimated.
- The degree of organizational adaptation required by each option is assessed.
- Economic, social, and institutional factors affecting each option are assessed.
- Specimens, samples, models, or prototypes may be developed for the more promising options.
- Solution or options are selected for further development and trial.

The tasks required during Stage I demand careful thought, planning, and evaluation. The effort necessary, especially to evaluate potential alternatives realistically, is frequently underestimated. Most of the failures of attempted innovations result from misjudgments made during Stage I in the process.[119 145]

The National Shipbuilding Research Program, described in more detail in Chapter II and in an Appendix case study, is doing an excellent job of carrying out the steps of Stage I. One facet of this program is an organized mechanism for diagnosing problems in the shipbuilding industry and for identifying possible solutions. The procedure for identifying new areas of research is based on a pooling of information among shipbuilders. Using a committee structure, shipyard representatives compile and evaluate existing problems and share their knowledge of technology that potentially bears on solutions. In the process of developing a research proposal for funding by the program, shipyards conduct a thorough survey of the resources of the shipbuilding industry as well as related or potentially supportive industries. Such surveys have occasionally produced solutions without the need for further research. If no ready-made solutions are found, the shipyards participate in deciding on the direction in which a solution is likely to be found through research. In fact, they help draw up the research specifications.[67]

STAGE II: PLANNING AND DEVELOPMENT

In the planning and development stage, a set of precise guidelines must be formulated to give concrete shape to the market, technical, performance, environmental, and personnel requirements of the proposed innovation. Although in practice some steps may be omitted, ideally, this stage includes steps such as the following:

- A procedure or mechanism for designing a plan to implement the innovation is created, or responsibility is assigned to an existing unit, either within or external to the firm.
- Existing technology is researched and scrutinized for applicability for implementing the innovation.
- The advice and experience of similar or related firms is reviewed and evaluated.
- Guidelines and plans for technical and/or marketing requirements are developed.
- Guidelines and plans for the management of economic, social, and institutional factors are developed.
- Guidelines and plans for organizational adaptation and support are developed.
- Experiments are conducted, if required.
- Procedures for evaluating the innovation are developed.

An important component of this phase is the search for additional information on existing technology and marketing practices that may be relevant to the proposed innovation. Frequently, it is possible to draw upon an existing pool of technological and marketing practices to satisfy some of the planning requirements. This information may come from inside the industry or from other related industries.

In developing guidelines and plans for implementing an innovation, considerable attention must be given to the development of procedures that will ensure organizational adaptation and support. As was previously noted, the development of guidelines for the adaptation of the organization to the innovation is called designing the embedding content of the innovation. The embedding content may include procedures for meeting safety and environmental standards and plans for reallocation of space and equipment. However, one of the most critical aspects of designing embedding content is the development of new personnel policies and procedures.

An important aspect of the planning phase is a clear understanding of the effect the innovation will have on the personnel involved. When changes are made in the way persons are expected to function, it is essential that their cooperation be obtained and that they be given the skills and understanding needed to perform in their new roles. Occasionally, new roles resulting from innovations may appear deflating, creating a feeling of loss of status, of doing something more routine than was done before. They may offer fewer opportunities for exercising judgment. If the changes are perceived in this way, workers will resist. If resistance is strong enough, it can be an effective barrier to adoption of the innovation, regardless of the innovation's technical soundness.

To avoid failure, workers must be trained in the skills necessary to use the new technology of the innovation. Specialized units within an organization or new roles for its personnel may have to be created. Changes in the organizational hierarchy or in lines of reporting and command may be required, particularly if a new organizational unit is established. New units and new roles require planning for new lines of communication.

The case of automated shipboard operations illustrates the need for careful attention to personnel requirements. Efforts to introduce greater shipboard mechanization in navigation, propulsion control, and fire and flooding control obviously involve more than technological innovation. The function of the crew is changed radically from human performance of these operations to monitoring and maintenance of the computerized control machinery. A new set of job definitions becomes necessary, and it must be recognized that these new job definitions will affect the self-concepts and motivations of crew members. Jobs must be more interchangeable, and job assignments more flexible. Efforts to introduce more automated control aboard Swedish ships were successful because careful attention was given not only to the technical requirements of automation, but also to the personnel necessary to support the introduction of the new technology.[119]

The LASH example cited earlier illustrates the importance of developing a clear understanding of the impact an innovation may have on the people involved. It also illustrates one type of adaptation that takes place when an innovation is put in place, i.e., the adaptation of the organization or system to the innovation. Often, a second type of adaptation also is necessary, i.e., the adaptation of the innovation to the organization. Seldom can any given innovation be lifted off the shelf or drawing board, or even borrowed from another industry or competitor, without some modification of its technological content. For example, a computerized billing system used by a railroad will probably require program modification prior to installation in a shipping company. These two forms of adaptation require substantial planning during the innovation process.

STAGE III: IMPLEMENTATION

During the implementation stage, the guidelines and plans formulated for adopting the innovation are incorporated into the operations of the organization. The objective is to ensure that the innovation is successfully utilized. A key requirement of this stage is the development of a demonstration or pilot program that tests, on a limited scale, the feasibility of the prototype project in terms of technical, economic, and worker performances. Unfortunately, the trial phase is sometimes omitted for one reason or another. Sometimes, to eliminate a technical or marketing problem, a solution is ordered into effect as though it were going to be permanent. Without adequate testing, the probability of success for a proposed innovation declines markedly. The failure of the proposed solution may, ultimately, harden resistance to innovation within the organization.

Ideally, the implementation stage has the following steps:

- A procedure for implementing the innovation is established, or responsibility is assigned to an existing department.
- The guidelines and plans developed during Stage II are applied in a pilot site on a trial basis.
- As difficulties arise, adaptations are made either in the technological content of the innovation or, more likely, in the embedding content. This may include changes in the guidelines.
- Evaluation procedures are applied to obtain data on benefits and costs.
- On the basis of the evaluation, a decision is made to continue, expand, or terminate the innovation.
- If the decision is to expand, steps are taken to extend the innovation from the pilot site to other

relevant sites within the organization (internal diffusion).

The likelihood of successful implementation can be increased by controlling the scale of the prototype pre-test. Limited-scale trial implementations or demonstrations are generally useful in generating evaluation data and providing an experimental atmosphere conducive to adjustments in the prototype innovation while also limiting the initial investment. Small-scale testing, however, is not without its limitations. It is important that testing be carried out under realistic field conditions, rather than being limited to laboratory conditions with their special supervision and support. The latter approach only demonstrates that the innovation can be implemented with specialized input, support, and attention, and does not constitute a real trial. In some cases, success may require a series of trials ranging from laboratory demonstration, to feasibility tests, to pilot tests on a small scale under actual field conditions.

The evolution of containerization, described in an Appendix case study, illustrates a successful maritime innovation. Although the military and MarAd had experimented with container units after World War II, the present integrated, intermodal container system began with an experiment conducted by a land transportation company. McLean Trucking, having acquired Pan American Steamship Company (later renamed Sea-Land), conducted a small-scale trial based on a new idea. The innovation to be tested was the shipboard carriage of trailers between U.S. Gulf Coast ports and New York. From this beginning, the present container system has evolved in stages, through trials conducted under field conditions. Several modifications were required in the original concept before an effective and economically efficient system was developed.

The first step, in 1956, consisted of carrying the trailers on specially constructed spar decks of tankers operating between New York and Houston. Having demonstrated the feasibility of the shipboard storage and carriage of trailers, the company designed a roll-on/roll-off trailership, an idea that was abandoned at the contract plan stage in favor of the more technically feasible and economical lift-on/lift-off principle. Six C-2 type ships were converted to full containerships, equipped with shipboard cranes for loading and discharging. The ships carried 226 thirty-five foot containers. The technical and economic attractiveness of the system was clearly demonstrated under these field operations. The subsequent success story of Sea-Land is well known. After this successful demonstration, the company instituted an intercoastal service in 1962, and, by 1966, had entered foreign trade with the system.[38]

The importance of the implementation stage is also evident in the adoption of containerization by Matson Navigation Co. This company, which operates a service between the U.S. West Coast and Hawaii, was having economic problems and decided that port productivity was a definite contributor about which something had to be done. To find a solution, Matson, in a move uncharacteristic of the industry, established an in-house research department to analyze its entire shipping operation and suggest improvements to the system that could solve the identified productivity problems. Using systems analysis techniques, including a computer simulation model, this department was able to analyze a number of possible changes. These studies pointed to containerization as the best option to consider for further development and trial demonstration.[160]

Like Sea-Land, Matson introduced the new system cautiously by carrying containers on the decks of conventional freighters. The success of these demonstrations led to conversion of a C-3 type ship, the HAWAIIAN CITIZEN, to a full cellular containership. During the planning and development as well as the implementation stage, Matson not only developed new technology, such as special terminal cranes, in support of the innovation, but also addressed the problems of labor and customer acceptance. Therefore, as the trial implementation progressed, the feasibility of containerization was demonstrated both in terms of technical design and in terms of meeting labor and marketing requirements.

The Matson project showed that field demonstration of the feasibility of an innovation can be considerably strengthened by a formal evaluation strategy. A solid program is necessary to evaluate the various effects of the instituted changes to ensure that the innovation is working at least as well as originally intended and that its benefits justify permanent adoption and expanded use by the company. If the organization cannot be convinced that the innovation is an improvement, the implementation stage may terminate prematurely with little gain and, perhaps, considerable loss.

Evaluation is an important part of implementation. However, it is difficult, and careful presentation of its purpose is essential. In presenting the case for wide-scale use of containers by Matson, for example, the proponents of the innovation did not promote containerization <u>per se</u>. Rather, they emphasized the cost savings and profits to be realized by using containers.

Generally speaking, the more visible the benefits, the more likely it is that the innovation will be adopted and diffused throughout the company. In his presentation to the committee, Foster Weldon, former Vice President of Research at Matson, explained that, at Matson, the proponents of containerization were sensitive to the problem of capitalization, including both the probable investment required and the difficulty of securing capital in an industry with a relatively low return on investment. To effect the changeover to an integrated intermodal system, management accepted a recommendation that a cost-reduction, debt-financing approach be used to create the capital needed to launch the innovation. This was achieved, in part, through the unprecedented West Coast Mechanization and Modernization (M&M) Agreement, an agreement between labor and management that called for a moratorium on the employment of additional Class A longshoremen to offset annual attrition in the labor force. In essence, a 5 percent annual attrition in labor provided a cost reduction that could be used to finance the capital indebtedness of container conversion. In this case, the benefits of the conversion were highly visible and well documented. The conversion was planned over an extended period of time, consistent with capital availability and effective market demand. The process was constantly monitored and evaluated to ensure that the innovation was achieving its prescribed goals.[160]

STAGE IV: DIFFUSION

Diffusion is the final stage in the innovation process. It emphasizes widespread application of innovations that have been developed in Stage II and implemented in a pilot or demonstration program in Stage III. The diffusion stage may have two phases, internal diffusion and external diffusion.

Within a firm, a successful pilot test or demonstration is usually followed by the decision to adopt the innovation and to apply it on a wide scale. The innovation can then become an accepted and widely used technical and/or marketing feature in the operations of the company.

Externally, other firms or industries may borrow an innovation from a firm that has successfully implemented and diffused it internally. Often, the borrowing process involves more than the simple transfer and application of the innovation to an existing operation. Frequently, the innovation must be scrutinized and tested for its applicability to the borrower's specific needs. This can require a repetition of the recognition and selection, planning and development, and implementation stages, perhaps in some abbreviated form.

Repetition of these stages may generate a number of modifications in the innovation to fit new and different circumstances. If enough borrowing and adaptation of the innovation takes place, standardized sets of specifications eventually may replace the single, original specific innovation. Standard sizes for container units are an example of the result of such borrowing and adaptation.

The diffusion stage is likely to incorporate the following steps:

- Mechanisms are established to ensure continuity of the diffusion process.
- Materials for the dissemination of the innovation are prepared, e.g., written and audiovisual materials, training manuals, etc.
- Information systems are established for storing and retrieving data about the operational use of the innovation.
- Communication channels are developed to promote personal contacts between the designers of the innovation and the adopters, as well as among adopters.
- Formal communication devices are provided, e.g., industry level workshops and conferences, and presentations at meetings of professional societies.
- Internal systems, with guidelines and criteria, are used to evaluate the effectiveness of the innovation.

If an innovation has been successfully implemented by a company, internal diffusion usually will not present many difficulties. It is important, however, to ensure that equal care and attention is given to the diffusion of both the embedding content and the technical content of the innovation. Just as the embedding content may be easily overlooked during the planning and development stage, so may it be neglected during internal diffusion. If this occurs, company personnel may begin to resist the diffusion of the innovation.

External diffusion will present its own set of hazards, particularly to the borrower. Again, the history of containerization provides an illustration. Although Sea-Land and Matson both developed integrated intermodal systems, their approaches to containerization had many technical and design differences. These differences reflected their different needs and different problems. One did not simply borrow the innovation from the other.

As container systems grew in popularity, these variations were at times ignored by steamship companies eager to reduce their own operating costs and improve their depressed profit margins. By failing to recognize the need to adapt containerization to their own particular situations, these companies failed to reap the expected economic rewards. The attempt to borrow a technology from either Matson or Sea-Land without going through the stages of the innovation process resulted in much lower odds for successful adoption of the innovation.

This problem can be compounded by an adopting organization's emphasis on engineering and design feasibility with inadequate attention to the embedding content. For example, Grace Lines, Inc., fared poorly in its early efforts to convert to container operations. With both Matson and Sea-Land setting the pace by converting to container service in domestic trade, Grace Line executives were eager to adopt this new concept and use it in foreign trade. Although Grace Lines was attempting to introduce the innovation in a more complex social, economic, and personnel environment, the company moved very rapidly into the implementation stage. With hindsight, it is clear that inadequate time and effort were given to planning and development. Vast portions of the embedding content of the innovation were ignored. As a result, when the first Grace Lines containerized vessel put into a South American port, the longshoremen were both unequipped and entirely unwilling to unload the ship.[38] After Grace Lines' failure to introduce containers in 1961, the federal government became overly cautious and did not encourage building of full containerships for a number of years.

BUILDING INNOVATIVE CAPACITY

The foregoing review of the stages of the innovation process illustrates many of the difficulties inherent in the process. Fortunately, a number of these difficulties can be avoided with practice. Indeed, practice in innovating tends to substantially strengthen a company's or an industry's innovative capacity. Innovative capacity refers to an organization's capability to absorb a series of innovations in a more or less regular manner. Introducing a single innovation -- even if it is successful -- does not ensure that the adopting organization will develop a continuing capability to innovate. Often the people involved in a single innovation are either those who have invented a given piece of technology and want to see it implemented, or those who have a particular organizational problem and are seeking a solution. In either case, they are concerned with the innovation process only with respect to a particular innovation. Their interest tends to wane when the innovation has been incorporated or the problem solved.

Although adoption of specific innovations and development of innovative capacity are both important, the latter has greater long-term impact. Unless an organization has such a capacity, efforts to innovate are impeded and costs are increased by what might be called the "reinventing the wheel" syndrome.

The innovation process is complex and requires the marshalling and application of specific analytic and evaluative skills. The innovation process begins when a company perceives an opportunity or a need to innovate. Then, an analysis must be conducted. The analysis results in the selection of a proposed innovation. A second period of analysis then ensues. It becomes necessary to determine how the innovation must be modified to fit the user and/or how the user must be acclimatized to the innovation. Similarly, after trial of the innovation, analysis is needed to determine whether or not it was actually beneficial to the user.

At each of these analytic points, systems studies, environmental studies, economic studies, and social and institutional studies may be needed. The various steps in the innovation process, as well as the various analytical studies that may be required, are all likely to be more easily, efficiently, and economically accomplished by a company that has focused on building innovative capacity as an organizational goal.

In general, the innovation process and the building of an innovative capacity can be facilitated by the assignment of responsibility for innovation to an individual or group within the company. Although such personnel may have responsibility for other company functions, they should be selected on the basis of their ability to carry out the kinds of activities that typically are a part of the innovation process. These activities include information exchange, planning, designing experiments and demonstrations, constructing models and/or facilities, testing, recording, analyzing results, and reporting.

Development of a research unit similar to that of Matson may be beyond the economic reach of many firms. Still, practice in innovation does expand the innovative capacity of a firm, and assignment to specific personnel of responsibility for introducing innovations ensures a continuing retention of access to necessary skills and an element of corporate memory. Thus, it is one of the most efficient means of ensuring the growth of innovative capacity.

CONCLUSIONS

- The basic elements and phases of the four-stage innovation process appear applicable to all innovations studied, recognizing, of course, that some stages may be truncated, while others might require several repetitions, depending on the specific innovation.

- Corporate assignment of innovation awareness responsibility and delegation of authority will help to institutionalize and build innovational capacity.

CHAPTER II

THE ROLE OF INNOVATION IN THE MARITIME INDUSTRY

The United States maritime industry is a complex of public and private enterprises that create, operate, maintain, and support the waterborne transportation of the United States. It includes shipper, consignee, forwarder, ship designer, shipbuilder, shipowner, ship operator, ship agent, ship repairer, port operator, terminal operator, cargo handler, cargo controller, inspector, insurer, and banker. It includes the personnel, the management, the facilities, and the equipment that are necessary to the functions listed above. It involves the contiguous transportation systems that complete the door-to-door service, as well as segments of national, state, and local governments.

Given the heterogeneous nature of the U.S. maritime industry, it is apparent that the history of attempts to innovate, the deterrents to the innovation process, and even the incentives that motivate innovators will differ from sector to sector of the industry. This complexity of industry structure has, of course, complicated our task as a committee. Nevertheless, we have been able to identify many incentives and deterrents that seem to operate in a variety of the sectors of the industry.

The very complex nature of this industry, combined with our physical and time constraints as a committee, necessitated that we focus our efforts on the oceangoing industry segment. We included in this analysis consideration of oceangoing vessels and of the port and shipbuilding industries that support this ocean activity.

A brief overview of the U.S. maritime industry is presented in this chapter, along with an overview of some of the sources of innovations useful to the industry and some of the evidence that the industry does not always make rapid and effective use of available new technologies. Finally, this chapter includes a brief description of one program, jointly sponsored by government and industry, that has been successful in promoting rapid development and utilization of new technology.

THE INDUSTRY

The United States has one of the highest standards of living in the world and correspondingly high labor rates. The one most important resource that helps offset the costs of high hourly rates is our high technical capability. By adopting innovations that make the U.S. maritime industry highly productive, it is hoped that the industry will become more competitive.

The U.S. maritime industry needs to be one of the world's leaders in technical and industrial competence. Its size must be adequate to support U.S. maritime objectives pertaining to the national defense and the national economy as outlined in the Declaration of Policy of the Merchant Marine Act, 1936. Title I, Section 101 states: "It is necessary for the national defense and development of its foreign and domestic commerce that the United States shall have a merchant marine (a) sufficient to carry its domestic water-borne commerce and a substantial portion of the water-borne export and import foreign commerce of the United States and to provide shipping service essential for maintaining the flow of such domestic and foreign water-borne commerce at all times, (b) capable of serving as a naval and military auxiliary in time of war or national emergency, (c) owned and operated under the United States flag by citizens of the United States insofar as may be practicable, (d) composed of the best-equipped, safest, and most suitable types of vessels, constructed in the United States and manned with a trained and efficient citizen personnel, and (e) supplemented by efficient facilities for shipbuilding and ship repair. It is hereby declared to be the policy of the United States to foster the development and encourage the maintenance of such a merchant marine."

Because every major maritime nation considers maintenance of a healthy merchant marine to be in its public welfare, the U.S. maritime industry must face foreign competitors who, like the U.S. industry, are aided by varying types and forms of cargo reservation and preference and by selective forms of government ship construction and operating subsidies, as well as other governmental financial assistance.[100 103]

There is a tendency to speak of the maritime industry as though it is one simple and homogeneous enterprise; it is in fact, three basic industry groupings comprising a complex of organizations that have the mutual purpose of moving the nation's waterborne commerce. These industry groupings --

ship operations, shipbuilding, and port operations -- have experienced varying degrees of economic success or failure and have shown different rates of technological progress. Each is examined briefly below.

Ship Operations

At the end of 1977, the privately owned, deep-draft, U.S.-flag fleet (including Great Lakes vessels) totaled 744 ships. While the number of U.S.-flag ships has continued to decline during the decade of the seventies, the total tonnage and productivity of the ships in the U.S. merchant marine fleet has increased due to larger, faster, more efficient, and technologically superior ships. Almost all of the net gains in tonnage can be attributed to the oceangoing component of the fleet. In 1970, there were 825 U.S.-flag, oceangoing ships; by January 1, 1978, this number had decreased to 578 ships. The total, oceangoing deadweight tonnage, however, had increased from 14.9 million to 17.5 million during the same time span. This represents a tonnage increase of almost 18 percent, most of which has been in the tanker segment.[14]

Table 1 provides a profile of the United States fleet from 1966 through 1976. The table shows that there has been a trend toward larger, faster ships. This, in turn, has meant increased carrying capacity and increased efficiency. Compared to the other major fleets of the world, the U.S. fleet is older than average. However, as Table 1 illustrates, some improvement has been made in modernizing the fleet since 1970.[104]

In spite of improvements in the fleet, the actual percentage of the total tonnage of the nation's foreign waterborne commerce carried by the U.S. merchant ships in 1976 had dropped to 4.8 percent (Table 2). It should be noted, however, that total tonnage of U.S.-foreign trade cargo nearly doubled between 1960 and 1976; therefore, this 4.8 percent does represent a rapidly increasing absolute weight. Nevertheless, when compared to the 58 percent carried by the U.S.-flag operators at the end of World War II, a substantial potential for improvement is evident.[39]

A closer examination of the U.S. merchant fleet and the ship operating industry reveals that there are substantial differences in current levels of success enjoyed by the different sectors of the fleet as defined by types of service sectors and vessels. There are three major service sectors the liner fleet, the non-liner fleet, and the tanker fleet.

TABLE 1

PROFILE OF THE U.S. PRIVATELY-OWNED FLEET
1966 - 1976*

Year	Age	Speed	Draft	Gross Tons	DWT
1966	18	16	30	10,700	15,500
1967	18	16	30	10,800	15,500
1968	19	16	30	11,000	15,900
1969	19	16	30	11,400	16,600
1970	19	17	31	12,300	18,200
1971	18	17	31	13,300	19,500
1972	18	17	31	14,200	20,900
1973	16	17	32	15,900	23,000
1974	16	17	32	16,800	24,700
1975	17	18	33	17,400	25,900
1976	17	18	34	18,300	27,800

* Age in years; speed in knots; draft in feet. All measurements are average values.

There are five general categories of vessels in the U.S.-flag liner fleet: break-bulk cargo carriers; full containerships; partial containerships; barge carriers (LASH and SEABEE vessels); and roll-on/roll-off vessels. In 1966, our liner fleet ranked second among maritime nations of the world on the basis of deadweight tons and seventh with respect to total number of ships. By 1976, these rankings had declined to sixth and eleventh, respectively. In all, the total U.S. liner tonnage declined by 28 percent during this ten-year period.[104] The greatest decrease in total numbers of ships has occurred in the break-bulk cargo carrier class.

However, the U.S. liner fleet has not declined in all vessel classifications. The number of ships in the unitized cargo classes has increased substantially. In the roll-on/roll-off category, the U.S. fleet ranks first in the world on the basis of deadweight tonnage. (Where U.S. is used to refer to tonnages and/or ships, it is to be read as U.S.-flag.) Table 3 illustrates the very high proportion of unitized cargo vessels operating under the U.S. flag in 1976 compared to the vessels of the other maritime nations in the world.

TABLE 2

U.S. OCEANBORNE FOREIGN TRADE/COMMERCIAL CARGO CARRIED

TONNAGE (Millions)	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Total Tons	387.6	418.6	427.5	473.2	457.4	513.6	631.6	628.9	615.6	698.8
U.S. Percent	5.3	6.0	4.6	5.3	5.3	4.6	6.3	6.5	5.1	4.8
Liner Tons	47.9	46.1	41.9	50.4	44.2	44.6	51.3	51.4	44.3	49.8
U.S. Percent	22.2	24.0	23.1	23.5	22.9	21.9	25.8	29.8	30.7	30.9
Non-Liner Tons	190.4	209.5	212.1	240.7	220.7	242.6	281.9	282.7	275.3	289.6
U.S. Percent	2.8	3.0	2.2	2.2	2.1	1.6	1.6	1.8	1.4	1.7
Tanker Tons	149.3	163.1	173.5	182.1	192.5	226.4	298.4	294.8	296.0	359.4
U.S. Percent	3.0	4.6	3.2	4.4	4.9	4.5	7.4	7.0	4.7	3.8
VALUE ($ Billions)										
Total Value	36.3	41.1	41.9	49.7	50.4	60.5	84.0	124.2	127.5	148.4
U.S. Percent	21.7	20.7	19.3	20.7	19.6	18.4	18.9	17.7	17.5	17.8
Liner Value	24.8	26.8	27.2	33.5	32.4	37.4	49.6	63.4	64.0	75.8
U.S. Percent	29.8	29.0	27.6	28.8	28.4	27.7	29.1	30.6	31.2	31.5
Non-Liner Value	8.6	10.8	11.1	12.2	13.2	17.4	25.2	34.7	36.6	38.2
U.S. Percent	4.5	4.6	3.6	3.3	3.1	2.4	2.5	2.3	2.8	2.8
Tanker Value	3.2	3.4	3.6	4.0	4.9	5.7	9.2	26.0	26.9	34.4
U.S. Percent	4.8	6.6	5.6	5.6	5.5	6.2	9.1	6.9	5.1	4.2

TABLE 3

PRIVATELY OWNED MERCHANT FLEETS, 1976*

Ship Type	United States		Other Countries	
	No.	Percent	No.	Percent
Break-bulk Cargo Carriers	113	37.8	11,471	90.8
Full Containerships	105	35.1	403	3.2
Partial Containerships	45	15.1	552	4.4
Barge Carriers	23	7.6	182	1.4
Roll-on/Roll-off Vessels	13	4.3	16	0.001
TOTAL	299	100.0	12,624	100.0

* Data derived from Merchant Fleets of the World; U.S. Department of Commerce; December 1977.

The U.S.-liner services have been faring somewhat better than the rest of the U.S.-flag fleet in garnering their share of U.S.-foreign trade. A unique combination of technology, financing, business management, government subsidies, and a healthy union environment has made the more innovative companies in our liner shipping industry profitable. Industry advances and new technology including containerships, LASH, and roll-on/roll-off ships, as well as governmental financial and cargo preference incentives, alert shipping company managers, and a cooperative work force have all come together in a timely fashion to ensure reasonable success. The delivery capacity of the subsidized U.S. liner fleet has increased significantly. The U.S.-flag share of liner cargo tonnage in U.S.-foreign trade increased from approximately 22 percent in 1967 to more than 30 percent in 1976 (Table 2). This was in spite of the fact that the fleet declined in numbers from 215 ships in 1970 to 166 in 1977. Despite inflation, the operating subsidy cost per unit of carrying capacity has declined by more than 10 percent since 1970.[14]

The U.S. non-liner fleet consists of three distinct vessel types -- ore and combination carriers, dry-bulk carriers (primarily grain ships), and the relatively new, fast growing area of neobulk ships. The dry-bulk shipping industry thrives as a vigorous business on the U.S. Great Lakes and rivers, but is almost non-existent in U.S.-flag ocean trade. There has been little domestic construction of deeper-draft bulker tonnage over the past decade, and there are now only 18 deepwater bulk vessels remaining under the U.S. flag. Most of these are nearing the end of their economic utility. While the U.S. bulk tonnage shrank by one half between 1966 and 1977, the world bulk tonnage increased by 330 percent. As a result, the U.S. bulk fleet is able to carry less than 2 percent of the U.S.-foreign trade in dry-bulk commodities.[104]

The U.S. tanker fleet, on the other hand, has been increasing in tonnage. Between 1966 and 1977, the actual number of tankers declined by 8 percent, but, because the new ships entering the fleet were much larger than those being scrapped, deadweight tonnage increased by 56 percent. By the close of 1976, the United States had 12 tankers that were over 100,000 deadweight tons; five of these were over 200,000 deadweight tons. Thus, the tanker fleet has been the fastest growing segment of the U.S. fleet.[104]

The 1970 amendments to the Merchant Marine Act of 1936 expanded subsidy programs to include both dry and liquid bulk vessels. The new subsidy arrangements were specifically geared to support a rapid increase in the numbers of U.S.-flag ships. To understand the initial impact of the 1970 Act, it is necessary to review characteristics of the shipbuilding sector of the maritime industry.

Shipbuilding Operations

Shipbuilding companies each have their own specialties and traditions. Complaints are often heard that the U.S. shipbuilding industry is antiquated and inefficient. Such generalizations do not adequately reflect the complex problem of producing ships in the United States. U.S. shipyards excel in the economical production of technologically advanced ships. They specialize in aircraft carriers, nuclear submarines, LNG carriers, navy destroyers, drill rigs, and so forth. These ships require a high degree of skill and technology. On the other hand, simple vessels, such as mid-sized, dry-bulk ships, are difficult for U.S. yards to build competitively. Such vessels ordered individually or in small numbers do not justify plant investment for mass production; so they are ideally suited for construction in the shipyards of developing nations, where the lower technological competence of the workforce is matched by lower wages.

When the Merchant Marine Act amendments of 1970 were passed, planners envisioned the construction of three hundred ships over a ten-year period. By 1976, only 62 contracts for ships, with an aggregate contract value of $3 billion, had been placed with U.S. shipbuilders.[139] The outlook for naval construction also is bleak. Contractual imperfections in the various naval construction programs have resulted in shipbuilder claims that, until recent settlements, totalled over $2 billion.[58] Unfortunately, the relationship between the shipbuilders and the Navy has been characterized by much acrimony.

A 1976 Pentagon report on the profits of defense contractors indicated that, for the five preceding years, the shipbuilders had the highest level of capital investment, but the lowest level of profit related to sales of any group of contractors. Since industry earnings have been far from satisfactory, industry improvements have been largely financed by debt capital. If profit margins remain low, funds for industry improvements may be even more difficult to secure in the future.[125]

In his February 1978 testimony before Congress, Robert J. Blackwell, Assistant Secretary of Commerce for Maritime Affairs, noted that total shipyard employment increased from 60,000 production workers in 1970 to 100,000 in late 1977. However, he predicted that there will be a sharp drop in shipbuilding employment within the next two years. The projected near-term employment fall-off cannot be offset by currently anticipated Navy and private orders. Citing the continuing, worldwide shipbuilding depression as a primary culprit, Assistant Secretary Blackwell pointed out, however, that the U.S. industry is not faced with the drastic retrenchment prospects confronting some foreign shipbuilding centers. He also noted that the flow of orders under the Maritime Administration's program has increased since the 1975-1976 contracting drought.[14] Still, shipbuilding prospects are discouraging, and the need for new approaches is evident.

Port Operations

Port efficiency is critical to the overall health of the U.S. maritime industry. The ship is recognized as only one link in the through-transport from producer to customer. It has been estimated that as much as 60 percent of port time and related costs for break-bulk cargo could be saved if the world's ports were to improve their ship, feeder, and cargo systems. These improvements have the potential of reducing port costs by as much as $15 billion and, in effect, increasing shipping capacity by 20 percent.[33]

On the surface, U.S. port operations may appear to be homogeneous. However, closer examination discloses unique combinations of technical operations, management styles, social conditions, and financial arrangements in each U.S. port. Some ports thrive while others flounder. In the San Francisco area, for example, the Port of Oakland, an innovative and aggressive port, is a successful operation, while just across the bay, the Port of San Francisco has difficulty.

MARITIME INNOVATIONS AND THE INNOVATION PROCESS

As a committee, we found that the topic of maritime innovation is not easily addressed. For too long, discussions of the innovation process have remained within the realm of the academic theorists. In the maritime industry, consideration of innovations has usually been limited to changes in ship design and/or engineering systems. In part, this report seeks to bridge the gap between the theoretical and the concrete. Only in this way can recommendations be generated that will improve the climate for technological change in the maritime industry.

The maritime industry has, for many years, been characterized as conservative and resistant to change. To determine whether such allegations are true or whether they mask the complex effects of deterrents to the innovation process, it is necessary to examine those characteristics of the industry as a whole that have a direct bearing on the innovation process. In addition, the origins, availability, and frequency of adoption of maritime innovations are reviewed.

The complexity of the maritime industry has been amply demonstrated. This heterogeneity has often had an adverse effect on the innovation process. Shipbuilding firms, ports, subsidized lines, unsubsidized lines, and labor each have their own unique perspective on any proposed innovation.

The history of the development of landbridge services, described in more detail in the Appendix, is a case in point. In 1973, two East Coast ports and a labor union filed a Federal Maritime Commission (FMC) action against 14 steamship companies that were offering bridge services between the Far East and U.S. East Coast ports. The landbridge operators had implemented the innovative services as a means of increasing utilization of their ships. Shippers were using the services because transit time was reduced at rates competitive to all-water transit. This successful innovation had, however, allegedly damaged other sectors of the industry. There were at least three categories of victims: all-water carriers, who were losing shipping contracts; conferences of all-water carriers, since the landbridge services were totally outside their control and placed them in competition they were organized to avoid; and the U.S. East Coast ports serving the all-water trade.[50]

In 1977, after four years of hearings, an FMC administrative law judge issued an initial decision in favor of the landbridge carriers. As an innovation, the landbridge has been very successful. Its impact on the current status of the maritime industry has been to shift the demand for port facilities from one coast to another, and it may have weakened the conference system in the U.S. trades. While it is beyond the scope of this report to judge the overall merit of the landbridge concept, it is clear that the complex structure of the industry had an effect on the introduction of the innovation, just as the innovation had simultaneously positive and negative effects on the different segments of the industry.

The number of innovations available to the industry has a real effect on the rate of technological change. We considered a detailed analysis of the origin of inventions and innovations available to the industry beyond our mandate. However, the availability of new technology is a critical ingredient in the innovation process.

Research and development efforts are a primary source of new technology. Yet, since 1964 when U.S. public and private spending on research and development reached a peak of 3 percent of the gross national product (GNP), such spending has slipped to the current level of 2.3 percent of the GNP.[64] Although the United States still retains an overall lead in total amounts spent on research and in numbers of new inventions, its economic rivals are expanding their research efforts at a much faster rate. Furthermore, the United States dedicates almost 50 percent of its research and development funds to defense-related projects while foreign competitors spend very little on military research.

In 1977, U.S. industry spent $17.5 billion on research and development for commercial markets. This represents a decline in constant value dollars over the past several years. Moreover, these expenditures are highly concentrated, with over 85 percent originating in just six industries: electrical equipment and communications; chemicals and allied products; machinery; motor vehicles; aircraft and missiles; and instruments. Industry funding of basic research also has declined dramatically, with two thirds of the annual expenditures of approximately $600 million concentrated in the first two industries named.[57] No figures for private expenditures on research and development in the U.S. maritime industry are readily available; however, there is no reason to suspect that the maritime industry differs significantly from other U.S. industries in its research expenditure trends.

Over the past several decades, the federal government has played an increasingly important role in the funding of basic research and development efforts. However, the percent of the total federal research and development budget used to fund the category "Transportation and Communications" dropped from a high of 5 percent in 1971 to an estimated 3 percent in 1977. Of the $702 million budgeted for this category in 1977, air transportation research received 61 percent; ground transportation research, 27 percent; water transportation research, 5 percent; multimodal transportation research, 3 percent; and communications research, 4 percent. Funds for water transportation research have decreased from a high of approximately $47 million in 1972 to approximately $32 million in 1977.[2]

One possible reflection of this national reduction in active R&D may lie in our foreign commerce of goods. The United States is importing substantially more manufactured goods than it exports. The U.S. trade deficit in manufactured goods for the first half of 1978 was $14.9 billion, while West Germany and Japan (with the help of high tariffs) were expected to run surpluses in manufactured goods of $49 billion and $63 billion, respectively.[64]

Decreasing financial support for basic research and for research and development efforts increases the importance of making rapid and effective use of inventions and other innovations that are already available. A number of important inventions/innovations have been developed in private research institutes, government laboratories, and university research programs. Examples include the large bulbous bow for low-speed ships, ship design economics, vibration reduction, seakeeping analysis, and ice-breaking bows; yet, the rate of adoption of these innovations appears slow.

The number of innovations that have been adopted in the U.S. maritime industry has been small compared to the apparent opportunities for technological change. Too often, experimental prototypes are developed and then abandoned, and too many inventions have been tested, but, for one reason or another, have not met with widespread acceptance within the industry. In some instances, inventions generated within the United States have been adopted abroad and, at least for a time, ignored at home. For example, some of the first LNG containment systems originated in the United States, yet overseas development of the systems has resulted in U.S. royalty payments as high as $1,000,000 for installation of foreign systems on U.S.-built ships.

Another example is computer-controlled steel cutting systems for use in constructing ship hulls. These systems were first developed in the United States. Finding no U.S. market, their developers sold them abroad. In 1973, the Maritime Administration (MarAd), in consultation with U.S. shipyards, selected and licensed the best of the foreign systems. MarAd then leased the rights to the system to interested U.S. builders.[68] Subsequently, a new and improved system was developed through the National Shipbuilding Research Program.

In other instances, maritime innovations are adopted by one segment of the industry and ignored by another. By 1960, successful container systems had been developed in the domestic trades by both Matson and Sea-Land. Yet, not until Sea-Land announced the inauguration of a weekly container service to Europe in 1966, did the majority of the owners of subsidized lines begin to move toward containerization. United States Lines, the dominant U.S.-flag operator in the North Atlantic at the time, quickly made design changes in five break-bulk/limited-container-capacity ships it then had under construction. As a result, United States Lines launched a fleet of jumbo-sized full containerships in 1968. Unfortunately, the company was, by then, two years behind its competition.[38]

Finally, a more contemporary example. MARISAT, the commercial satellite communications service for the marine world, became operable in 1976. Institution of this system marked the beginning of a new era in ship-to-shore communications. The system provides constant, high-quality service and can be used both at sea and in port. Yet, even now, few ships have installed equipment needed to make use of MARISAT.[121]

To demonstrate the benefits of this communication system, MarAd sponsored a project jointly funded with industry. The project included installation of the equipment aboard several U.S.-flag ships, creation of a computer-based message handling system, and development of plans to facilitate use of the system. However, the project did not include development of model computer programs that would link on-board computers with home-office management information system computers. Few companies are now willing to undertake the investment required to develop such computer software on an experimental basis.[86] This innovation seems to be stalled because neither industry nor government is willing to invest in the full development of the innovation's embedding content.

There are many other examples of maritime innovations that have been available to the industry but have either not been widely adopted or have been adopted at a very slow rate. Nevertheless, MarAd's efforts to encourage innovation in the industry have become increasingly effective. One of the mechanisms used by MarAd to strengthen the innovation process has been to support university research projects. The purpose of such projects is usually to develop technological innovations. However, it is becoming evident that research in the area of the innovation process itself, particularly the embedding and the diffusion of innovations, should receive the attention of both government and industry. Such research could serve to clarify many issues and lead to the development of improved embedding and diffusion techniques.

Innovations that require major capital investment and/or a significant amount of organizational change are less readily adopted. However, not all innovations are large. Many innovations can be characterized as relatively low-cost, incremental improvements in methods, materials, or machinery. In many industries, the principal source of such improved products or methods is outside the industry itself.

Unfortunately, most segments of the U.S. maritime industry lack the necessary economic leverage to induce supplier industries to develop new products. For example, shipbuilders spend more for steel than for any other material. Yet, their purchases total less than 2 percent of the total steel mill output.[68]

Though the industry is small and lacks the economic power to stimulate suppliers, it does make use of a wide spectrum of related technologies. Therefore, innovations in other transportation industries, the construction industries, and the chemical industries may be successfully appropriated. To undertake successful borrowing of technological advances requires that some means of defining the needs or problems faced by the maritime industry be developed. It also requires a concerted effort to search for useful technological advances occurring outside the industry. The following example describes a program that has been particularly successful in helping one segment of the industry define needs and search for technological solutions. It also has been judged successful in stimulating innovation.

A MODEL PROGRAM

Recent R&D expenditures by the shipbuilding industry may be an exception to the generally declining trend in R&D spending described in the preceeding section. The National Shipbuilding Research Program represents an increase in directed government/private R&D funding in the shipbuilding industry.

The National Shipbuilding Research Program is jointly sponsored by MarAd and the Society of Naval Architects and Marine Engineers (SNAME). The program was launched in 1969 and is operated on a shared-cost basis with government and industry acting in partnership to identify and assess technical problems and develop solutions. The results of program-sponsored projects are made available to all members of the industry. The program has approximately 100 projects either completed or in progress. Many of the projects have been successful; some have failed. The organization and techniques used have permitted the program to exploit its successes through wide industry diffusion. The program also incorporates mechanisms that permit the recognition of failures in time to avoid large expenditures of resources.

A number of barriers had to be overcome in the course of implementing this program. In general, industry is distrustful of government projects and project personnel. Government antitrust activities cause additional worries on the part of industry, especially about participating in the development of a program that seeks cooperative fact-finding among companies. Historically, companies within the same industry have been highly competitive. This, of course, reduces information exchange. Finally, industry often views government as being unable to carry out long-term commitments. The government's team was able to overcome problems in each of these areas through planning, patience, and sincere effort.

The structure of the program does much to encourage open communication. The cosponsorship by SNAME provides a critical link in this process. SNAME acts as a conduit for information about the program, as well as for information about advances made by other MarAd-sponsored projects. Each project is conducted under the direction of a program manager housed within one of the industry's shipyards. The program managers are held responsible not only for supervising the individual research and development projects, but for disseminating information about the projects to the rest of the industry. Conferences are held periodically to assess new industry needs, and open, on-site demonstrations of each piece of new technology developed through the program are mandatory.

The following are the critical factors that contribute to the success of the National Shipbuilding Research Program:

- User participation in the development of research and demonstration priorities and project specifications;
- Rising expectations among shipbuilders about the potential benefits of the program for the industry;
- Open communication and exchange of technological information among participants;
- Cost-sharing among participants;
- And, most important, a rare, open partnership between government and industry.

A detailed description of the operation, successes, and failures of the National Shipbuilding Research Program is contained in the Appendix. The strategies developed through this joint effort may well be worth emulating in other sectors of the U.S. maritime industry.

CONCLUSIONS

- The U.S. maritime industry is both complex and heterogeneous. Its segments often have conflicting interests. The shipbuilding firms, the ports, the subsidized lines, and the unsubsidized companies each have their own perspective on any given issue. The fragmented structure and internal conflicts of the industry make the introduction of new ideas difficult.
- Research and development efforts are a primary source of the new things and methods that stimulate innovation. Yet, in general, there has been a serious decline in the level of funding for research and development projects in the United States over the past several years. Federal funding for U.S. maritime research has followed the general decline.
- There are and have been many technological advances that offered potential economic reward to the U.S. maritime industry. Many were adopted slowly and/or are not currently in use. In some instances, foreign competitors have been the first to adopt these U.S. technological advances.

- Many excellent ideas are developed in research programs in private research institutes, government laboratories, and universities. Recent examples include the large bulbous bow for slow speed ships, ship design economics, vibration reduction, seakeeping analysis, and ice-breaking bows.

- The limited size of various segments that comprise the industry makes them an uneconomical market for the development of major components of equipment, either by the industry itself or by suppliers to the industry.

- Although the maritime industry is relatively small, it draws on a wide spectrum of related technologies. Consequently, it is possible for innovations in other industries, such as construction and aerospace, to be of interest to the maritime world. While the marine industry cannot afford to support research and demonstration projects in all areas, the industry would benefit by carefully monitoring exterior developments and adapting them to the maritime field when appropriate.

- When the federal government works closely with industry to assess industry needs and develop research priorities, there is a high rate of implementation of the results of federally funded research. Cost-sharing programs sponsored by the Maritime Administration have proven particularly effective.

- There is evidence that the shipbuilding industry has been accelerating its rate of research and development. This is being heavily influenced by the success of the cooperative MarAd/SNAME Shipbuilding Program. A similar effort has not developed between the ship operators and the MarAd research and development program. Clearly, there are strong benefits to be derived from such a program.

- The National Shipbuilding Research Program has utilized limited resources effectively. It is expected that, while substantial government support will continue to be required, the shipbuilding industry will increase its financial commitment to the development of new technology.

CHAPTER III

ENVIRONMENT FOR INNOVATION

The U.S. maritime industry does not exist in a vacuum. Rather, like any industry, it is inextricably woven into the complex social, political, and legal fabric of the United States. Thus, some of the incentives and deterrents to innovation and technology transfer in the maritime industry have their origins outside the industry itself and are essentially beyond industry control; most are not, however, beyond industry influence. To influence factors beyond the immediate control of industry requires first that these factors be identified, and second that they be analyzed and positive directions for change be charted.

In the course of our deliberations on the environment for innovation, we identified and analyzed four major influencing factors of external origin. Even though these factors are essentially external to the maritime industry, they have a significant impact on the climate for innovation within the industry. The first factor is the public perception of the maritime industry, a factor that has social origins and political consequences. The second factor, protectionism, has political and economic origins and both legal and economic consequences. The final two sets of factors are laws, legal decisions, regulations, and rules; and the tax structure. These last two groups arise primarily from the federal government and from the various international, multi-lateral treaties that regulate the worldwide maritime industry. Each of these factors is seen as having an important effect on the rate of innovation and technology transfer experienced by the U.S. maritime industry. Each will be discussed in this chapter.

PUBLIC PERCEPTION OF THE MARITIME INDUSTRY

One of the deterrents to progress in maritime innovation and technology development is the lack of public perception of the U.S. maritime industry as a significant component of the U.S. transportation system. One hundred years ago, U.S. ships dominated our commerce and captured the imagination of the American public. Forty years ago, passenger ships provided nearly all ocean business and pleasure travel. Now, with the advent of air travel and space exploration, public interest in ocean travel and ocean transport has waned.

The public lacks interest in today's merchant marine partly because it is the least visible sector of the U.S. transportation network. Few Americans have any contact with ships. Other modes of transport, especially air transportation, are far more visible. Aerospace innovations are spectacular and receive widespread public attention, while advances in the maritime industry generally go unnoticed. As a result, the U.S. merchant marine is perceived by the public as outmoded, inefficient, and noncompetitive. The industry's need for subsidy has added appreciably to this poor public image.

General public apathy has prompted policy makers to tend to dismiss maritime power as non-essential.[139] Yet, the Merchant Marine Act of 1936, as well as the 1970 amendments to the Act, stipulate that the merchant marine should continue to serve important national functions. The merchant marine is described by federal law as the basic logistic transportation service for the military in times of emergency. The defense of essential sea lanes is considered necessary not only to maintain a steady supply of strategic goods during war; but, it is also deemed essential to ensure a constant flow of raw materials for U.S. industries during peacetime. In spite of this expressed and legislated national policy, the very real threat to national security arising from the decline of U.S.-flag shipping and the rise of other maritime powers, especially the Soviet fleet, goes unnoticed by many policy makers and by the majority of the general public.

It is clear that a means must be found to increase the public's awareness of the importance of the merchant marine. Unfortunately, the economic realities faced by the maritime industry will make this difficult. A recently published study sponsored by the Maritime Administration sought to establish the economic impact of the U.S. maritime industry. Using 1970 as the base year, the researchers found that sales of goods and services for the industry totaled $8.3 billion; payments for goods and services totaled $2.4 billion; wages and salaries totaled $2.3 billion; corporate income totaled $0.8 billion; and federal, state, and local tax revenues totaled $0.7 billion.[39] As impressive as it looks, this $14.5 billion total represents a very small share of the $2 trillion U.S. economy.

This small share of the GNP is not really indicative of the benefits rendered by the maritime industry to U.S. trade and national security; it does, however, help explain why the American public is unaware of the high percentage of U.S. trade carried by foreign-owned, foreign-controlled ships and by U.S.-owned, foreign-flag ships.

Not only is economic leverage lacking, but the potentially harmful economic consequences of a declining U.S. merchant fleet are not readily apparent to the public. Many believe that foreign nations with large fleets and low cargo rates should carry U.S. cargo, thereby saving the United States the cost of maintaining its own shipping capability. It is not generally recognized that reliance upon foreign shipping may leave the United States vulnerable to the arbitrary actions of foreign trading partners such as those experienced during the oil exigency of 1973-74.

Subordination of long-term economic goals to short-term savings on freight rates reduces the ability of U.S.-flag operators to generate capital for investment in innovation or construction and weakens the fleet's ability to respond to commercial and defense demands.

Even those recruiting new talent for the industry are affected by public apathy. Recruiters find it difficult to attract high-quality personnel for managerial and engineering positions (see Chapter V). Schools that teach naval architecture and marine engineering report a substantial portion of their American undergraduate students are originally attracted because of their interest in yacht design (though they often expand their interest with time). Then, when qualified undergraduated students apply for graduate study in marine-related engineering programs, few can be admitted because of the meager and uncertain research support available to U.S. universities in the maritime field. In short, there is a lack of concern about national maritime prestige, national maritime power, and the concomitant national security considerations.

However, the most dangerous result from the lack of public awareness is a lack of understanding of the crucial role of U.S.-flag cargo ships in national defense. During the Viet Nam conflict, 98 percent of all military support flowed by ship -- the widely proclaimed airlift notwithstanding. The vigorous public promotion of airlift is probably responsible for the low level of public perception of the important support role the U.S. merchant marine played.

The U.S. airlift of military equipment and supplies in support of the Israeli war was a huge success. This success was made possible because the jet fuel for the airlift, which weighed four times as much as the equipment moved, was delivered by ships.

The American public is basically unaware of the function of the merchant marine and the need for maintaining a commercial fleet. This lack of awareness hampers industry growth. It also handicaps the industry in its efforts to introduce innovations or technological changes that will strengthen the U.S.-flag fleet. This important problem suggests an opportunity to innovate to increase public awareness of the national importance of the maritime industry.

PROTECTIONISM

Nations that enjoy a high standard of living have been characterized by highly productive workers. High productivity thrives in an environment involving high capital investment in equipment, mass production, strong managerial leadership, innovative engineering talent, enlightened labor-management relations, and a political environment that lends support to the industry with a minimum of interference. Under these circumstances, workers can earn high hourly wages because their high productivity generates labor costs per unit that are no higher than those generated in less advanced nations. Even when unit costs are higher, the industry may maintain a competitive edge by offering a more desirable product. Better products are made possible through market surveys and advanced technology. However, under the high hourly wage rates that prevail in advanced nations, an industry that maintains labor-intensive methods will seldom be able to compete in the world market.

Supplying some form of protection is often suggested as an equalizer to enable labor-intensive industries to compete in world markets. Little direct evidence exists to demonstrate the effect of protectionism on the innovation process. Nevertheless, this impact can be inferred by examining the relationship between protectionism and economic motivations. Of interest is the contrast between the ship operating industry and the shipbuilding industry. Some ship operators have been able to move away from a labor-intensive approach and toward a capital-intensive approach without benefit of direct subsidy; the shipbuilders, however, have not, even with the benefits of a variety of protective laws and regulations.

None of the usual forms of protectionism completely eliminate competition or the profit motive. However, many do tend to reduce competition and, to that extent, must be considered deterrents to the innovation process. Cabotage (the legal restriction to domestic carriers of transport between points within a country's borders) and cargo preference laws are absolute reducers of competition in the sense that they limit competition to domestic fleets.

Bilateral agreements and conferences allow more flexibility, but attempt out of national interests to exclude predators who would invoke pressures external to shipping economics.[116] Other forms of protectionism such as federal mortgage insurance are weaker deterrents because they do not lower the survival and profit motives.

It has been argued, with at least some justification, that shipbuilding is inherently labor-intensive, and, therefore, the United States must continue some form of federal encouragement if the industry is to survive. Considering the extremely cyclical nature of the U.S. shipbuilding industry described briefly in Chapter IV, if shipyards are to maintain any continuity in trained engineering and production staff, if they are to avoid having to hire and fire according to the fluctuations of the order books, some form of federal protection is required.[55] In addition, to be competitive internationally, many U.S. shipbuilders and ship operators require protective arrangements to compensate for higher costs which are caused by the expense of compliance with higher U.S. environmental and safety standards.

Even though the U.S. shipbuilding industry benefits from federal subsidies and other forms of protection, it has lagged far behind its foreign competitors in introducing innovations. Although there has been a distinct recent move toward making the industry more capital intensive, it would be difficult to show that U.S. shipyard workers are now more productive than those in nations where labor rates are only a fraction of those in this country.

The effects of direct subsidy for ship construction and ship operation are difficult to gauge. Some believe that such subsidies encourage complacency and reduce competitive spirit. Others feel that, since subsidies are available to all U.S. fleets, competition is not greatly affected within the industry itself, and that competition with foreign maritime nations is impossible without this form of federal support.

The attempts of the subsidized U.S. lines to build containerships in U.S. yards are often delayed by the restrictions and bureaucratic constraints of the subsidy program and, because of the uncertainty of receiving government construction funds, shipyards often delay or fail to invest in the necessary machinery. To illustrate, Grace Lines, Inc. awarded a design contract to Sun Shipbuilding Co. for four containerships in late 1961. The construction contract for the ships was not awarded until mid-1963. The delivery date for the first ship was the spring of 1966, and delivery of the last in spring 1967. In contrast, a Chilean line awarded a design contract for four containerships to a

Japanese shipyard in spring 1963; delivery of the first ship took place in the fall of 1965; by spring 1966, the last ship was delivered.[97] The Chilean project was completed in one-half the time of the U.S./Grace Lines project.

Although the federal bureaucratic procedures were not the only contributing factors in this case, they were a major factor. At the time, many U.S. shipyards, including Sun, lacked the machinery needed to produce containerships efficiently. The failure of subsidized lines to take early advantage of the pioneering work of the unsubsidized lines, compounded by the lengthy delays encountered during the design and construction process, seriously weakened the competitive stance of the U.S. fleet in world trade.

In the last several years, many U.S. ship operators have made a strong move toward capital-intensiveness. Crew members are fewer in number than in years past, and they are working with ships that are ten to twenty times as productive as the vessels they replaced. Moreover, some U.S. shipowners have led the way in certain technological developments. Often, the most innovative companies have been those operating without direct subsidies.

The two companies, Sea-Land and Matson, that first undertook independent development of containerships were not directly subsidized. Although it should be noted that both Matson and Sea-Land benefited from cabotage and cargo preference laws, as well as indirect aids such as Title XI mortage insurance, their capacity to operate in world trade without benefit of direct subsidy must be largely attributed to better management and careful pursuit of the innovation process. Containerization was not adopted on a wide scale by subsidized lines until after Sea-Land launched its first foreign trade container service.

One condition that is basic to the various forms of federal assistance is that the government must be assured that the recipient will meet the requirements of the law. As a result, there are a plethora of restrictions and legal activities and paperwork. The complexities of federal maritime interventions and labor union constraints place enormous administrative burdens on U.S. shipowners, particularly those who accept operating subsidies. These shipowners usually are unable to make rapid adjustments to changing opportunities either in the market or in the availability of new technologies. Preoccupied with administrative matters that are the inevitable consequences of federal support, subsidized shipowners have less time or little inclination to try new concepts. Moreover, when legal requirements become outmoded, these restrictions are often difficult to change and often hold back progress.

Subsidies have been cited as being responsible for the poor management of several U.S.-flag ship operators. Testifying before the House Merchant Marine and Fisheries Committee in February 1978, Assistant Secretary of Commerce for Maritime Affairs, Robert Blackwell, stated that, of the ten U.S. liner companies receiving operating subsidy, one (PFEL) was in bankruptcy and two others (Prudential Lines and States Steamship) "are in a condition that is of concern." He said the major nonsubsidized liner companies (Sea-Land, U.S. Lines, and Central Gulf) all operate profitably. Regarding the contrast between the performances of the subsidized and nonsubsidized liner companies, Mr. Blackwell ventured that the nonsubsidized carriers, generally, had extremely good management and that, if they weren't the recipients of subsidy, the other operators "would probably work harder."[108]

It may be, however, that some more indirect forms of federal aid to ship operators and shipbuilders could provide the same economic protection while encouraging more technological change. Two outstanding examples of how other countries have supported innovation through indirect means are found in the U.K. and Japan.

The United Kingdom has developed a number of financial support programs that directly encourage the adoption of innovations. To support development of the new industries such as the hovercraft industry, Britain established the National Research and Development Corporation which provides venture capital to projects considered to be in the national interest. The aim of the corporation is to be financially self-supporting from the commercial operations of the projects it has funded. Of the $9.5 million invested in hovercraft projects, the corporation has already recovered over $5.7 million.[40] Clearly, there are possibilities for the development of U.S. indirect subsidy programs. This issue should be studied in more detail, as should the issue of developing tax programs designed to encourage the adoption of new technology.

In Japan, the first automated seagoing ship, KINKASAN MARU, was produced under a government program started in 1959. The Shipbuilding Technical Council, at the request of the Japanese Ministry of Transportation, established subcommittees and instituted a joint effort by shipbuilding, shipping, and related industries to assist in the program. The Ship Bureau of the Ministry of Transportation coordinated the project's research activities.

The Ministry of Transportation continued its efforts, and, in 1967, established an ambitious program to further advance automation technology by bringing together representatives of the shipbuilding industry, shipowners, component suppliers, industry and university research activities, and classification societies to function as members of the Joint Research Committee on Advanced Integrated Control Systems for Ships. The cooperative efforts of this group were instrumental in producing a series of highly automated merchant ships between 1969 and 1973.[76]

LAWS, LEGAL DECISIONS, REGULATIONS, AND RULES

Statutes and regulations are the means by which Congress and regulatory agencies, such as the U.S. Coast Guard, the Labor Department's Occupational Safety and Health Administration, and the Environmental Protection Agency, promulgate their policies. Many of these laws and regulations purport to encourage innovation as a matter of policy. At the very least, they do not deliberately attempt to inhibit innovation.

However, in the past five years, the time it takes to promulgate regulations has increased beyond the needs of democratic process. Legalistic and bureaucratic delays place many issues in limbo, so that industry holds back on research and application of innovative ideas while awaiting the outcome of regulatory delays. The process could be quickened appreciably with benefit to the innovative process without threatening the democratic process.

Inability to establish source-to-destination bills-of-lading for through passage in international land and water carriage of intermodal containers results from existing laws that act as deterrents to the innovation process. For instance, land and water segments of intermodal movement are regulated by two independent agencies, the Interstate Commerce Commission and the Federal Maritime Commission. As presently written, antitrust laws related to rates for such carriage also block this needed change.

Patent laws and policy can act as both a stimulus and a deterrent to inventors. Strict patent laws are intended to protect the financial interests of inventors and, therefore, encourage technology growth. However, many federal research and development contracts require that any patents flowing from work on the contracts be available to all.[68] The underlying notion is that since publicly funded research led to the patent, everyone should benefit. As R.B. Hannay notes, the problem is that what belongs to everybody usually is of interest to nobody. The large investments required to manufacture the resulting new product and develop a market are unlikely to be rewarded by a satisfactory economic return in the absence of an exclusive license. Hannay notes that patents resulting from federally funded research and development projects could become a stimulus for the adoption of new technology if new provisions for exclusive licensing were established.[57]

Uncertainty created by changing government attitudes and policies is another deterrent to technological change in industry. The net effect of this uncertainty is to shorten the time-frame within which management is willing to plan. Thus, cautious, small improvements in operations may be approved by management, while long-term, capital-intensive innovations are avoided. Therefore, the many, often radical changes that have occurred in the federal regulatory area over the past two decades continue to act as deterrents to technological change.[57]

International policies are expressed by the world community through multi-lateral treaties from conventions such as the Safety of Life at Sea Convention (SOLAS). The policies developed by the convention participants may also influence technological change, primarily because the process of ratifying and revising such conventions is time consuming and requires obtaining the approval of a majority (often two-thirds) of all parties involved. Each country must carry out those actions required for internal treaty ratification and revision of domestic legislation. The time required for this ratification slows the pace of technological change for all of the treaty participants.

In another way, however, international organizations such as the Intergovernmental Maritime Consultative Organization (IMCO) help the U.S. maritime industry by adopting standards in their agreements that force competitors to emulate America's generally higher environmental protection and safety codes. These agreements probably have little or no effect on innovation within the U.S. industry because U.S. standards are usually the bench marks for international agreements, and, of course, they already prevail in the U.S. maritime industry.

Other maritime regulations promulgated as rules of non-governmental organizations, such as labor unions and the classification societies, may either encourage or discourage innovation. For example, unions generally have opposed actions that bring about greater mechanization in the operation of ships and ports out of fear of losing job opportunities for their members. Most classification societies, on the other hand, have tried to steer a middle course in setting minimum requirements. Overly stringent rules will drive shipowners to competing societies; overly relaxed rules will lead to frequent losses and deterioriating credibility in the eyes of shipowners and underwriters. Overall, however, classification societies tend to err on the side of gradualness in setting minimum requirements for innovative technologies. This conservatism initially acts to slow progress, but without such prudence innovative developments may suffer embarrassing failures that could lead to the application of even greater conservatism.

Finally, there is the body of maritime or admiralty law promulgated by the courts and regulatory agencies that is based on the results of litigation between disputing parties. Since the first responsibility of these organizations is to reach a just decision on the matter being tried before them, the policy implications of such decisions are less likely to be considered. In general, the precedents set by such decisions can be altered only through the slow legislative process.

There is a strong tendency for legal and quasi-legal rules to inhibit progress. What is a wise rule in today's milieu may be foolish tomorrow. Yet, laws and rules are not easily changed, and so they often prevent the quick adoption of new technologies or new methods of operation.

Governments in other countries, especially Japan, work more closely with industry to foster innovations and exports. At times, it appears that the U.S. government has adopted a hostile attitude toward business, subjecting it to thousands of costly regulations. For example, in the making of steel, companies must comply with more than 5000 regulations issued by 27 different federal agencies.[1] The national legal/regulatory structure has become counterproductive as a public service tool. The net public interest would be better served by simplification and reduction of the regulations on private enterprise and by added incentives for innovation.

TAX STRUCTURE

Tax issues that are relevant to innovation include the treatment of capital gains, investment credits, depreciation, and the tax treatment of research and development expenses. Little has been written about how tax incentives affect innovation. While some argue that tax incentives do encourage firms to innovate, others maintain that there is no evidence to suggest that tax incentives will encourage firms to apply retained earnings to the development of new products.[49]

Although experts disagree about the effects of tax incentives on research and on innovation in industry generally, in our investigation, we found that there is little disagreement on the dampening effect of the current tax structure on innovation in the maritime industry.

The capital gains tax structure has been cited as being one reason for the drying up of venture capital. The maximum tax on capital gains was raised from 25 percent in 1969 to the recent 49 percent rate. For investors, this increase effectively cut what might have been a 25 percent gain on a high-risk investment to an effective return of about 12 percent. Even with the recent congressional roll back of the capital gains rate, the negative effects of ten years under the old structure may continue for a while into the future.[64]

It appears that the current U.S. tax structure tends to discourage innovation, particularly capital-intensive innovation, in two significant ways. First, depreciation is calculated on the basis of historical costs and does not recognize recovery of current or replacement value. Although future recovery of book value is allowed, the purchasing power of the value recovered will have been significantly reduced by inflation. Hence, an investor must earn a higher after-tax profit in order to maintain his capital in real terms. Second, taxes are based on a percentage of before-tax profits. If an innovation loses money and there is no income from other sources, the investor must absorb a substantial portion of the loss. Profits, however, are shared with government, roughly on a fifty-fifty basis. Thus, the potential profit, which would normally act as an incentive to encourage industry to undertake the risks of innovation, can be reduced substantially by taxes. Under this structure, it is not surprising that industry tends to ignore innovations that do not promise quick, high profit margins.

The U.S. maritime industry differs from most others in that it is in direct competition with foreign industries, many of which are owned or controlled by their respective governments and have been effectively shielded from the exigencies of the free market. Special economic and tax considerations have been granted the U.S. industry via the Merchant Marine Act of 1936 as amended in 1970 through creation of tax deferred construction fund accounts. Additional special tax considerations such as short-term write-off of capital investments and revised calculation of depreciation would aid the industry in service of the public welfare by improving the climate to innovate and would not necessarily adversely affect other industries.

One approach for changing the tax structure is offered by W.E. Zimmie, President of Zinmite Corporation and well-known innovator. Zimmie believes that the current maritime subsidy system suppresses creativity. In place of the present subsidy system, he recommends a more rapid tax write-off, claiming that it would provide a more effective incentive for innovation. If this method were adopted, he suggests, a productive and profitable innovation would automatically pay for itself through rapid write-off. The Canadians, for example, offer a variable time-frame for tax write-offs.[166]

Philip Abelson, editor of Science magazine, cites high interest rates and current tax policy as two factors that discourage innovation. He supports rapid write-off by citing as a contrast that in Japan companies can write-off capital expenditures in 3 to 5 years; in the United States, write-off time is 10 years or more.[1] Of course, the opinions of Zimmie and Abelson are only two among many views that must represent a wide range of judgment on the complex issue of the levy and use of government taxes.

CONCLUSIONS

- In general, the public is unaware of the economic, defense, and security-related contributions of the U.S. maritime industry. This makes it difficult for many sectors of the industry to secure funds for research and development projects and to attract qualified managerial and engineering personnel. It also makes it difficult to attract qualified undergraduate students to maritime-related engineering programs. While many qualified students apply for graduate study in marine-related engineering programs, few can be admitted because of the meager and uncertain research support available to U.S. universities in the maritime field.

- The volume of regulations and standards as well as the time required for the promulgation of regulations place a variety of constraints on business operations. Examples include operating subsidy regulations, industry standards, work rules, steamship conference arrangements, and classification society requirements. Although it is unintentional, these regulations sometimes serve to delay or inhibit the introduction of new devices and methods.

- Direct federal subsidy of segments of the industry appears to have a dampening effect on innovation. The quality of management in subsidized firms has been cited as being lower. However, there is evidence suggesting that indirect subsidy arrangements may stimulate innovation and improve the quality of management.

- Federal tax and accounting structures tend to discourage innovation by reducing financial benefits. The current method for calculating depreciation, high-capital-gains tax ratios, and the lack of special tax treatment for profits and losses associated with high-risk innovations tend to discourage investment in innovations.

CHAPTER IV

ECONOMICS AND INNOVATION

The committee assumed instinctively that, during peacetime, the strongest incentives for innovation are economic. Our belief was strengthened by the observations of a number of authorities who have studied the innovation process in this country.[148] In general, both potential profit and economic necessity tend to stimulate innovation, while economic complacency tends to act as a deterrent. An economic inducement to innovate may be mitigated by either or both of two factors, capital availability and/or the perceived risk of the innovation. We made no attempt to conduct any detailed economic analyses such as application of the sophisticated Hechscher-Ohlin theory of factor pricing and international trade (which assumes a freely competitive model market that does not exist in the maritime industry). We leave such analyses to the economic theoreticians. Instead, we have looked at the economic motivations for innovation including profit, economic necessity, and complacency; capital availability; and perceived risk. We conclude with an assessment of the perceived role of innovation in the maritime industry, primarily in financial terms.

PROFITS, ECONOMIC NECESSITY, AND COMPLACENCY

The more prosperous industries in this country have learned to foster innovations; they have learned that investments in research and development pay good returns.[61] Authorities agree that for-profit organizations are more likely to innovate successfully than are government-supported entities.[70] However, many government agencies, such as the U.S. Navy, have been able to show money-saving returns arising from the application of research and development findings. The role of innovations in reducing local tax burdens has been recognized, even by urban politicians.[62]

These facts have not been lost on the maritime industry. For example, a desire for an improved economic climate and for improved profits was a major incentive in the recent growth of the Port of Seattle which, by deliberate effort, has become a multi-purpose, multi-terminal port.[33] The development of the LASH ship by Prudential Lines was also stimulated chiefly by a desire for profits.[129] It is not surprising, then, that when economic pressures are attenuated by subsidy, protected trade, or other forms of government support, the incentive to innovate may be correspondingly reduced.[108] In turn, the prospect of profits commensurate to the risk is, without question, a major driving force behind innovation.

In Norway and Sweden, a major and readily identifiable effort directed at development of practical shipboard automated systems was initiated in the late 1960s. From the outset, it was recognized that both the cost of introducing automation and the risks involved would be high. However, it was also realized that the ultimate payback to the entire industry would be extremely attractive. Having identified the magnitude of the task as well as the potential benefits, successful programs were initiated with the support of all sectors of the industry -- shipowners, shipbuilders, maritime unions, government, classification societies, and university and industry research facilities.[76]

Economic necessity can be the mother of innovation, as well as invention. For example, in the case of Matson Navigation cited earlier, the company was faced with the hard choice of either finding a way of reducing its port costs or increasing the rates charged to shippers. Since the latter would invite dangerous competition, the company conducted research and decided to move into the relatively new area of containerization.[38 160] Similarly, the conditions of over capacity on many container trades provided a strong economic incentive to increase utilization by whatever means possible. Hence, the development of landbridge services.[50]

Organizations that are in decline are often motivated to innovate because of the sheer economic necessity of trying something new and, usually, the availability of the required managerial and engineering manpower. However, if the decline is caused by an industry-wide slump, pessimism within the boardroom or at the banking establishment may actually discourage technological change.[61]

There is an important contrast in the fact that, while Matson introduced containerships out of economic necessity, Sea-Land introduced them because the profit potential was so apparent.[38 160] The economic forces were working in the same direction for both companies. The difference was that Matson was pushed into innovation; Sea-Land was drawn.

Economic complacency acts as a dampener of the innovation process. Studies confirm the common observation that private companies have little time or inclination to innovate when order books are full.[61] There are, of course, exceptions, such as when a company has plenty of contracts but is still losing money. Under these circumstances, the first likely innovation may be new faces in top management. Moreover, these new managers may be brought in precisely because they will innovate. In more typical cases, however, full order books mean comfortable economic conditions, and no one wants to cause unnecessary upsets when things are going well. With the organization going all-out to meet its commitments, it is unlikely that any managers or engineers will find or make time to innovate.[61]

As was noted earlier in the discussion of subsidies, even when order books are not full, managers of protected industries tend toward economic complacency. We as a committee have observed that federal intervention in free-market operations inevitably places a balancing burden of constraints on the recipients of public largess. Thus, if economic necessity is absent and the normal desire for increased profits is diluted by complacency and/or federal protection, technological change will falter.

CAPITAL AVAILABILITY

An innovation usually, though not always, requires capital investment. An economic motive to innovate will not always be sufficient to carry the idea. The availability of capital to support innovation is a complex subject. Again, the experts disagree.

In a 1973 study, Barriers to Innovation in Industry, a principal finding with respect to venture development and financing for innovation was that there is no shortage of venture capital. In fact, the study found that there are vast pools of institutional and private capital actively seeking venture investment opportunities that are qualified and prudent. Deterrents to the investment of venture capital identified in the study included the high risk involved, especially during start-up; the length of time in which the investment is not liquid; the effort required by the initial investor to monitor and evaluate innovative ventures; and bank constraints that deter the sponsorship of sophisticated technology. As a consequence, venture capital is tending to shift into less technical, lower risk situations that are at a relatively later stage of commercial evolution.[83]

Coincidentally, an infusion of government-controlled venture capital offers no solution. Research has shown that the most likely result of the infusion of large amounts of government capital is to drive out private capital. When the government comes in, it will not take the high-risk ventures; rather, it funds the good risks, thereby driving out private venture capital.[120]

In the discussions on tax policy, subsidies, and depreciation, we assert that the problems of private investment in innovations and the development of capital are closely tied to these issues. Although, it is a complex subject, it offers significant possibilities for stimulating private investment in new technology.[57] Such possibilities have not been adequately explored, however.

On the gloomier side, for many years there has been inadequate capital for new plant construction or at least insufficient incentives for capital investment. As a result, in some important industries, such as steelmaking, shipbuilding, and railroad transport, technology that is already available has not been fully exploited. Therefore, there is little incentive to invest in still more advanced technology. Jerome Wiesner cites as an example, "We know that smooth-riding, 200-or 300-miles per-hour (or even faster) trains are possible, but who will pay for them and who will put them to work?"[161]

The findings of a recent study uphold the idea that some proposed innovations are abandoned because of a lack of capital. Based on an examination of 200 industrial innovations that were stopped by management decisions some time before successful commercial application, the lack of capital was found to be a barrier to adoption of the innovation in 15 percent of the failures.[32]

In his presentation to the committee, W.E. Zimmie addressed the availability of capital to support the adoption of innovations in the maritime industry. He noted that return-on-investment (ROI) has, in recent years, been low in the maritime industry. Many U.S. ship operators and shipyards have earned less than a 5 percent return on investment, even in "normal" times. Therefore, they cannot afford to indulge in extensive research and development because, especially for shipyards, trying a new idea involves too much risk. Because of the need to guarantee new ship performance for a year and the low return which affords no real buffer, shipyards avoid risk and stay with often outmoded, but proven, systems. A consistently low rate of return also limits the amount of investment capital the industry can attract. With little investment capital, there is minimal incentive to assume the risks associated with adopting innovations.[166]

PERCEIVED RISK

The difficulty of acquiring capital is one of the consequences of the perceived risk of innovating. However, when managers are considering the risks of innovating many other factors must be studied. Peter House and David Jones[61] delineate one important consideration that is of particular interest to the maritime industry. The cyclic characteristics of the business, especially the shipbuilding industry, tend to magnify the importance of risk. For example, between 1955 and 1975, the number of commercial deadweight tons (in thousands) contracted for construction in U.S. yards fluctuated from lows of 123.0 in 1954, 178.3 in 1962, 161.4 in 1965, and 573.3 in 1971, to highs of 1940.7 in 1956, 954.9 in 1967, and 2984.6 in 1972.[55]

Historically, these cycles in the shipbuilding business have made the manning decisions of management more difficult. Large numbers of production workers, designers, and engineers have been laid-off during slumps and rehired during peaks. Management decisions regarding other resources such as expansion of facilities, purchase of new equipment, and other long-term capital investments necessary for innovation are more difficult to justify under fluctuating workloads and manpower levels. When there is a peak or feast, companies are preoccupied with maximization of short-term benefits; during the decline, long-term capital for innovation and expansion is difficult to obtain. Unfortunately, when the industry is in a business slump or trough and there are few ships to build, the conservative manager with the less modern or backward shipyard may do much better than the pioneering manager with the highly automated productive yard.[10]

If an innovation does not perform as expected, there is a risk of incurring costs associated with downtime for an entire system. The failure of the innovation may cause the entire unit (e.g., a ship) to be removed from service in order to restore the malfunctioning system to service, or to perform required modification. In either case, downtime costs will be incurred.

An example of concern about this type of risk was described by Reuven Leopold. He studied innovation adoption in naval ship design and related it to downtime repair and/or replacement due to failure of the experimental item. Leopold found that the U.S. Navy tends to disapprove a new concept unless it is shown to be cost-effective in its initial installation, as projected over its life cycle. He states that the navies of other countries are willing to look upon the initial installation of a new concept as an investment that may pay off in second or third generation fleet applications.

Leopold also says officers in charge of naval ship procurement are extremely cautious about cost and delivery schedules. In their eagerness to carry out their responsibilities, they have little sympathy for innovative ship design and building. Innovation in their eyes may bring minor benefits in the final product, but will, in many cases, escalate costs and disrupt schedules.[79] Parallel pressures exist in the merchant marine, where the pressure to minimize costs is as great as in the Navy.

We noted that the U.S. Navy and the Maritime Administration devote great attention and large sums to innovation and experimentation. They have, in the past and present, designed and constructed numerous ships for wholly or partially experimental reasons -- on occasion, ships of radical types and, frequently, ships incorporating major innovative technological advances and new concepts. The federal government can afford such risks because a smaller proportion of the total national system and capitalization is jeopardized. On the other hand, for a private enterprise, the perceived cost of downtime repair and/or replacement due to failure of experimental items is a most significant barrier to the introduction of an innovation.

When an innovation is being tested, the cause of ship downtime is not always hardware failure. One extreme example occurred on the N.S. SAVANNAH. The crew became dissatisfied and walked off the ship. The ship was idle for the year it took to select and train qualified replacements to operate this nuclear powered prototype.[162]

An innovation may require a substantial capital investment in order to achieve success. When a very large investment is needed to introduce an innovation, there is an added necessity of proving that a large enough market exists to justify that investment.[61] The uncertainty of securing the large market is a perceived risk beyond any technical considerations of the innovation. The introduction of intermodal containers described earlier required modification of a large fleet of cargo ships as well as major port-side investment. The cost associated with the ship modifications and related technological changes was of such magnitude that wide adoption of the idea was delayed nearly two decades.[38]

Another perceived risk that may reduce the willingness of management to innovate is the risk of losing their job if they make a bad decision. This perception is very real to middle and upper management and is usually caused by the lack of an innovative environment or capacity within the company. The most innovative companies are often the smaller, new companies where people feel free and, in fact, are encouraged to propose and test new ideas while following the basic design outlined in Chapter I. In an environment where job security is the most important factor in decision making, the safest path, i.e., the status quo, will most often be chosen.

Insurance firms naturally tend to be extremely cautious in underwriting untried concepts. The N.S. SAVANNAH, for example, could not have operated without congressional backing for protection and indemnity insurance. A decade ago, when Great Lakes shipowners first became interested in winter navigation, most were discouraged by what seemed to them to be unrealistically high insurance rates set by the underwriters.

When asked to quote a rate, marine underwriters, by tradition, place heavy emphasis on past performance. Innovative plans can offer little or no history, so most underwriters react by protecting themselves with relatively high rates. The one Great Lakes fleet that was able to go out and prove the safety of winter navigation was one that was self-insured, the U.S. Steel Corporation's Great Lakes fleet.

Experience has shown that people are often preoccupied with problems that have a low probability of occurrence. Many of the environmental problems studied are of this general type. One example is the possibility of a dangerous gas cloud from a damaged liquefied natural gas (LNG) carrier. The U.S. has great difficulty accepting the risks associated with LNG import, even though other countries, many of which import as much as 96 percent of their LNG by sea, offer a history of operation without major incidents. In addition to anticipated problems, there are unanticipated and/or undefined environmental problems that may develop at some future date. A proposed innovation often elicits this fear of the unknown; thus, a paradox exists, for in order to overcome the fears associated with an innovation, it must be put into use and demonstrated to perform satisfactorily on a day-to-day basis. There have always been a few leaders who perceived the potential gain as justifying the risk of the unknown (see Chapter V); however, for many, the unknown potential environmental impact of an innovation serves as a substantial barrier.

Even after the best of marketing studies, the possibility exists that customers may be slow to utilize new systems or services. Acceptance is not automatic. One of the deterrents to technological change can be unexpected or unanticipated shifts in the market. Of 200 innovations that faltered or failed in the marketplace, a post-mortem analysis showed that over half were still judged by management to be "good" innovations.[32]

CONCLUSIONS

- The strongest motivations to innovate are economic, whether they arise from the incentives of potential profit or the pressures of avoiding economic catastrophe.

- Because the maritime industry is capital-intensive, high-risk, and, often, low-profit, there is great reluctance to introduce new technology that will increase risk without assuring a commensurate increase in profit.

- Because of the cyclic feast or famine nature of some segments of the industry, there is minimal long-term capital planning. The feast phase tends to cause preoccupation with maximizing short-term benefits. The prospect of a famine phase makes long-term capital difficult to obtain. The famine phase itself generates shortages of both manpower and capital for innovation.

- A merchant ship represents a major capital venture. Any loss in operating time entails a major expense as fixed costs continue. Therefore, owners are hesitant to try new technologies or new techniques that may entail unplanned downtime.

- In many instances, abnormally high insurance costs inhibit shipowners and bankers from investing in innovative ships or new operating procedures.

CHAPTER V

PEOPLE AND INNOVATION

The people involved in an attempt to develop new technology or launch an innovation are critical to the success or failure of the project. In studying what is known about these people, we divided the examination into three major areas. The relationship between the activities of the management and the personnel as they operate as either incentives and/or deterrents to the innovation process was analyzed in detail. The role of the innovation promoter, called here a linker or champion, was also examined, as was the specific role of labor in the innovation process.

There are many factors that affect management decisions and can thereby inhibit innovation in all industries, but some are particularly germane to the U.S. maritime manager. Any business executive can identify easily with the classical admonition, "Be not the first on whom the new is tried." Few people or groups of people manage to do anything right the first time. True pioneers can expect to meet more than their share of dead-end paths and booby traps. He who lags back just a bit can often take advantage of the leader's mistakes. Unforeseen technical problems almost invariably increase costs or decrease income, particularly in the early stages of development.[161] With a ship, a failure of even some small component may force a prolonged out-of-service period, a prospect few owners care to risk.[27] The reasons behind this reluctance to trigger change are particularly pronounced among shipowners. A merchant ship with a price tag of fifty to one hundred million dollars is obviously an expensive subject on which to experiment.

Competitors (other ship operators, railroads, etc.) may force delays through regulatory agencies or may meet the challenge by adopting even better innovations.[50] Like managers in other industries, the maritime manager confronts many organizations that can sometimes cause delays of prospective maritime innovation: underwriters, standards associations, classification societies, unions, and government agencies to name just a few. In addition, problems can be created by the previously cited weakness of our patent system and fear of federal antitrust laws.

Other factors that discourage managers and innovators arise from the cyclical nature of the industry and the consequent uncertainty about the future business environment. Since adoption of an innovation can sometimes require reorganization of a company, managers will be reluctant to change, and this will also have a dampening effect, especially during financially lean times.

In the face of such odds, how do maritime personnel react when an innovation is suggested? Ship managers, for example, may avoid the adoption of any innovation that has the potential of being a highly visible mistake. Understandably, they prefer to make the less obvious mistake of clinging to traditional ways. As is noted in the following discussion of effectiveness in management, there is reason to believe that the maritime industry's collective managerial talent, like other industries, contains its share of such ultra-conservative individuals.

EFFECTIVENESS OF MANAGEMENT

To understand the relationship between management activities and the incentives and deterrents to innovation and technology transfer, we examined various categories of managerial performance that were related to the rate of acceptance and introduction of new technology. The group of activities so identified is intended to be representative, and, thus, should suggest actions that may tend to bolster the effectiveness of management.

In our free enterprise economy, management must anticipate the short- and long-term consequences of each managerial act. A proposal for a project may be viewed as a bundle of short-term and long-term opportunities and problems. The effective manager must be able to anticipate the magnitude of the opportunities and problems, assess the relative risks and rewards, and reach a logical and timely decision.

Sometimes, the secondary benefit of a project may exceed the benefit of the primary mission. For example, in a 1975 case study, E.H. Tempest emphasized the secondary benefits that can accrue from the government contracting procedure. In this study, the contractor learned the technology necessary to build the new type of electronic device required by the government contract. After building several units for the Navy, the contractor went on to market a commercial product. The sales of the product and the resulting growth of the company were substantial. Thus, because management anticipated the long-term benefit that could be derived from the project, the company prospered.[149]

Effective management must also consider and evaluate the short- and long-term problems of a proposal. It must have a plan for evaluating the performance of innovations and the willingness to terminate an innovation that is not proving beneficial to the company.

The inbred conservative attitudes of management can be a significant deterrent to success. Such conservative attitudes surfaced often during the initial years of the National Shipbuilding Research Program. Program staff encountered such problems as industry distrust of government projects and project personnel, industry worries over government antitrust activities, lack of cooperation within the industry, and the perception that the government was unable to make long-term commitments.[68]

For a company to overcome resistance to change, management must provide an organizational environment that motivates members to be innovative. Change is a way of life. Resistance to change is also a way of life. The only way that successful change can take place is to overcome the resistance to it and provide the proper organizational conditions to enhance it. Encouragement should be offered to stimulate progressive thinking. Failures and setbacks should, generally, not be punished by loss of jobs or loss of professional status.

One example of the need for effective planning in the maritime industry is illustrated by an article in Container News. Because of the efficiency of modern fast containerships and jet air freighters, consignments often move faster than the accompanying paper work, insurance, and customs procedures. Management needs to step in and improve archaic systems for handling such things as customs, payments, insurance, and customer clearances.[127]

A recent article by Blair Little and Robert Cooper addresses management inadequacies in planning and how the lack of planning acts as a deterrent to innovation. The promoters of many potential innovations do little or no marketing research because they feel that such research will produce either the wrong answers, vague and inconclusive answers, or no answers. Yet, marketing research is essential if management is to make informed decisions.[84]

It has been argued that one of the shortcomings of management in the maritime industry is its inability to carry out sound, long-term planning. Harry Benford looked at the forecasts made in the post-World War II period. He found that only seven developments predicted by management actually came into being; six predicted developments fell by the wayside, while a total of forty-one developments that were not foreseen have materialized.[8]

In traditional industries, change is incremental. Innovations of major technological and economic significance tend to come from outside the target industry, e.g., from foreign technology, from independent inventors, or from new, small firms.[136] A recent Office of Management and Budget study of the impact of federal research and development funds found that small businesses accounted for almost half of all major innovations in a period from 1953 to 1973, and that small businesses produce four times as many innovations per researcher as big businesses.[52] Aggressive, flexible management is one, but probably not the sole reason for this difference. Since the maritime industry has a solid, traditional orientation, and because it is larger and older than many industries, its management tends to reflect solid, tradition-oriented views.

Management's failure to keep informed of the rapid growth of technology and to try to understand its potential is a deterrent to innovation. Donald Schon summarizes his findings by saying that industries that are old, linked to their past, and based on crafts tend to lack entrepreneurship, generate low profits, invest little in new technology, and possess a heavy commitment to old methods and equipment.[136] An increasing number of industries are prospering because of their attention to the importance of obtaining young, effective managers and engineers, and upgrading experienced personnel already in middle and top management and technical positions.

In focusing on the effectiveness of management and, in particular, sources of maritime industry leadership, Harry Benford offers some interesting statistics. Approximately a decade ago, the average annual output of naval architecture undergraduate degrees was believed to be 35 in the United Kingdom, 55 in the United States, 300 in Japan, 1,200 in the People's Republic of China, and 7,500 in the USSR (figures are credited to F.H. Todd). Benford says, "The arresting fact is that the United States is lagging far behind the world's leading maritime nations in this respect."[10]

There are a number of examples that illustrate the importance of effective leadership in stimulating the adoption of innovations. The current availability of the MARISAT system is one case. The originators of MARISAT call the new satellite communications system the most significant advance in maritime communications since the advent of wireless telegraph.[114] Prudential Lines has leased MARISAT systems for its four LASH vessels. Because the new communications system is unaffected by weather, ionospheric conditions, or by frequency crowding, Prudential is able to deal with port and weather scheduling problems and use the expensive LASH vessels to the best advantage. Although the advantages of the system have been demonstrated and are well recognized, a recent report in Seatrade indicates that diffusion of satellite communications to other shipowners has been slow, as few companies have been willing to invest in the necessary accompanying software.[86]

The role of education is strong in encouraging innovation. Better educated managers and workers seem to be better able to utilize research results and are more inclined to invest in research and development.[94] Harry Benford looks into the future in his paper, "Of Ships and Shipping, 2000 A.D.," and suggests that education and training may be one of the most important challenges to management. He notes: "The net result will be to render obsolete those individuals and organizations that cannot adapt to change. The secret of survival lies in continuing aggressive research and development spurred by more and better educated engineers and managers who have been taught to teach themselves."[8]

Elsewhere, Benford makes three salient points about the relationship between education and professional development in the maritime industry. First, there is a consistent and long-term demand for naval architects and marine engineers, even during periods of economic slump. Second, innovative designs are sometimes delayed or avoided because of the shortage of engineering talent. Third, other industries have learned the value of persons educated and trained in the maritime arts and recruit them away from the maritime industry with very attractive offers.[10]

A low level of professional development can limit the use of new technology. For example, William Carey points out that one of the reasons that local and state governments do not participate in research and development that could result in needed innovations is because they lack the necessary technical capacity and information capacity.[19]

The United States seems at least partially deficient in needed educational resources. Although there are a number of qualified maritime academies that educate and train persons for shipboard careers, and a host of universities with excellent graduate programs in business administration, the fact remains that only a handful of our engineering schools offer programs in naval architecture and marine engineering.

LINKERS AND CHAMPIONS

While effective managers may be essential to successful innovation, effective management may be an insufficient stimulus to innovate. Often, for innovation to go forward, an innovation promoter is needed. The innovation promoter may, but need not be, found within the management strata of a company. Indeed, he or she may not be within the company at all. The innovation promoter may be an individual or firm marketing a new technology, or a member of an information exchange organization. In general, there are two types of innovation promoters, linkers and champions.

Several studies have shown that the presence of an effective individual, office, or organization that serves to promote ideas through technology exchange and/or information exchange is often critical to the innovation process.[37 41 158] Usually, these linkers do not go on to become personally involved in the innovation or assume a leadership role within the adopting company. Rather, they carry the idea only to the point where it is recognized as having promise by those who may implement it. However, their role in the process appears to be important, if not spectacular.

Another type of promoter could be called a leader, but is, perhaps, better termed a champion. A champion played an important role in many of the cases studied by the committee, including the development of the National Shipbuilding Research Program and the development of the LASH ship. In each of these cases, the innovation appeared to progress to the adoption stage mainly as a result of the champion's vigorous and skillful promotion.

Champions are important to the innovation process. Although many ideas have reached the adoption stage without a champion, many innovations would have taken much longer to be adopted had they not had champions. The champions were often more than leaders. Some of them appeared to have been inspired by deep personal conviction. Malcom McLean, the champion of containerization at Sea-Land, is an excellent example.[38]

In some cases, of course, personal conviction could outweigh good judgment to the point that misapplications are promoted, but these cases are the exception rather than the rule.

LABOR'S ROLE IN INNOVATION

The issue of the role of labor in innovation in any industry tends to polarize points of view. Labor has the potential for hindering the innovation process in the maritime industry, as Grace Lines discovered when introducing container operations in South America, and as the Maritime Administration discovered when trying to put the N.S. SAVANNAH in service.[38 114] Innovations that may result in a significant saving in manpower can call forth strong opposition. Typically, labor strives to maintain the current level of manpower and the status quo in jobs. Labor leaders are also quick to argue that the desire of maritime workers to preserve their jobs coincides with the national security requisite of maintaining a large pool of well-trained maritime manpower.

Management may stand at the opposite extreme. For example, Donald Schon, in his article "Innovation by Invasion," writes:

> We pay a price for technical change. Traditionally, we have paid the price by supporting the victims of change: by subsidies, tariffs, import quotas. But this technique has not worked. It has merely deferred the eventual decline of obsolete industry. Henceforth, we must promote industrial mobility: the ability of industry and workers to move to new skills and new regions.[136]

In spite of this dichotomy of views, innovation can go forward. Looking to foreign nations, we find examples of success in establishing a role for labor in the innovation process, such as the Japanese industries, as well as examples of failure, such as the industries of Great Britain.[67] The U.S. maritime industry has a mixed record of success and failure. Joseph Goldberg has the following comments concerning the U.S. maritime industry:

> The labor force has been organized, entry limited, retirement eased and liberalized, and flexible utilization increased. These and additional factors have made for assurance of work opportunities and earnings, even in the face of immediate dislocation and possible future decline in jobs.[80]

Improved techniques of collective bargaining should be able to ameliorate the potential problems of innovation related to labor. For example, shipboard mechanization, which resulted in a reduction of crew sizes, has been accepted cooperatively by maritime labor for nearly a decade. This acceptance has been predicated on the premise that "reasonable" manning would be retained. Reasonable manning has been interpreted as a level that allows for proper navigation and maintenance of vessels.

Adjustment agreements reached through collective bargaining may include providing advance notice of the intended implementation of an innovation, providing training and retraining, assuring no job lay-offs, providing other forms of job protection, relying on attrition, instituting "red circle" wage rates (i.e., maintenance of salary level for employees holding jobs that have been downgraded), providing seniority protection, assuring rehiring rights, instituting early retirement, providing "bridge benefits" for early retirees, spreading the work, assuring transfer and relocation rights, and providing severance pay.

While this array of benefits may be considered the responsibility of management, labor has its own share of responsibilities. The willingness of labor to work with management to improve productivity and the capabilities of personnel through training programs is critical to the growth of the industry. Labor can greatly strengthen the innovation process by learning new skills and trades as old skills and trades become obsolete. Of course, if labor is to participate in this way, they must be forewarned about impending changes by management.

Most labor leaders feel that technological advances and increased productivity should be encouraged as long as the benefits are shared by both labor and management. For management, this means increased profits and operational efficiencies, leading to increased ability to compete in the world market and, possibly, higher profits. For labor, it means higher wages, job security, and attractive fringe benefits.[153]

An approach used with some success at Litton's Ingalls Shipyard has been the Labor-Management Committee, which was established in 1965. Forty to fifty top management personnel meet monthly with an equal number of representatives from fourteen unions. Both the management and the union representatives find that the meetings serve a useful purpose. Union people believe that their concerns reach the right management ears, and management finds the committee structure useful as a vehicle for obtaining union input on the formation of company policy.[85] Similar committees could undoubtedly smooth the way for many proposed innovations.

CONCLUSIONS

- An effective manager can act as a stimulus to innovation within a company. Effective managers are those who are able to understand all facets of new proposals, including both the potential short-term and long-term benefits. Generally, they are flexible and receptive to new ideas and are good planners and capable leaders.

- The innovation process in all industries, including maritime, would be enhanced by employment of an increasing number of well-educated engineers and business managers.

- Lack of awareness about new technologies and/or a lack of accurate and timely information about the uses and benefits of new technologies act as a barrier to innovation in the maritime industry. Essentially, it is the responsibility of management to make the effort to maintain an awareness of the state of the art in new technology. This management function must be adequately discharged for a company to remain competitive and to optimize new business opportunities.

- The climate for innovation is enhanced when management and labor cooperate in planning change and in the transition phases of the introduction of new technology and new techniques.

CHAPTER VI

INFORMATION AND INNOVATION

As noted in Chapter II, expenditures for research and development (R&D) in the United States have not grown at the rate necessary to maintain the country's creative edge in many technological areas. The percentage of the U.S. budget provided for research and development has declined over the past several years. To complicate matters, private venture capital no longer seeks investments in high-risk, long-term research and development efforts. In 1972, 104 small research and development firms were able to raise seed money on the various stock exchanges. In 1978, only four were able to do so.[64] Consequently, President Carter has expressed his concern about stagnant U.S. technology. Recently, he established an interagency committee to conduct a comprehensive review of issues and problems related to industrial innovation.[89]

Research is fundamental to the development of new technology; therefore, it has a pivotal role to play in innovation. To be sure, innovation can occur without research. Technology can be transferred from industry to industry; a company can borrow a successful practice or piece of hardware developed by a competitor. Nevertheless, at some point in the history of any innovation, a researcher usually will be found. Even technology transfer, whether it is between industries or between similar companies, usually requires some level of research sophistication. It is rare that a new technology or practice can be borrowed wholesale; rather, a series of adaptations must be made by the borrower. These usually take place through a testing process, though, at times this may consist of trial and error. Yet, the worlds of the researcher and the business manager are usually far removed from one another, and this gap can be a significant deterrent to innovation.

A related factor that affects the rate of innovation and technology transfer in industry is communication and information exchange. One means of overcoming the gap between researcher and potential user is to develop new patterns of communication and new ways of exchanging information. The transfer of technology from point to point is, of course, wholly dependent upon communication and information exchange. It is reasonable to conclude, therefore, that more communication and speedier information exchange could accelerate technology transfer in industry.

In our deliberation, we looked at what happens to the innovation process when there is no effective communication between researchers and users. We also sought to identify the ways that people in the industry exchange information, and looked for ways to improve communication, and close the gap between research and practice.

THE GAP BETWEEN RESEARCHERS AND USERS

Various authorities have documented an important factor that researchers often overlook, namely, that new ideas and new findings are apt to go unheeded unless there is a need for them as perceived by the user.[41 61] The final phrase is underscored because we have observed that, within the U.S. maritime industry, there are a fair share of managers who appear to be unaware of the potential benefits of research in general, or of what their own needs are in particular.

In some instances, of course, the need is obvious. Frank Ebel cites such a situation. After Sea-Land introduced container service in the North Atlantic, shippers quickly saw the advantages of containers. Sea-Land's competitors were forced to innovate at once or go out of business.[38] Frank Dashnaw's report on the development of the highly skewed propeller is another good example. Here, shipowners had a bad vibration problem and recognized that an innovative propeller might effect a cure.[30] The Port of Seattle's modernization plan serves as an example of how an accurate perception of the needs of shippers led to the development of excellent container-handling facilities as well as highly sophisticated information systems. The result was an amazing revival of the port as a center for international trade.[33]

In recent years, the Maritime Administration's Office of Commercial Development has made serious efforts to fulfill MarAd's congressional mandate to emphasize the type of research that the industry says it needs. Toward that end, MarAd has cooperated with the U.S. Coast Guard, U.S. Army Corps of Engineers, Seaway Authorities, and others to stage several industrial conferences. The primary aim of these conferences has been to elicit a list of potential research projects and rank them according to need. In addition, MarAd often requires that companies share in the cost of research. The willingness of companies to do so provides a direct measure of the perceived importance of the research.

Although the wisdom of listening to the perceived needs of industry is unquestioned, relying on this approach alone is often not enough. As previously mentioned, there are managers in the U.S. maritime industry who are seemingly unaware of their own needs. Moreover, even those who are aware are often ignorant of the vast amounts of research already available to them. Some of the blame must be borne by the research fraternity, which has failed to establish a record for effective articulation, much less salesmanship. These shortcomings are evidenced by the proportion of maritime researchers who are content to write their reports in their own language (integral signs) instead of the language of industrial decision makers (dollar signs).[119]

This failure of communication works in both directions. For whatever reasons, researchers frequently misunderstand the real needs of industry and so go about solving the wrong problems. The maritime industry is probably not any worse in this respect than any other. But, with so pitifully little research being conducted in the field, and with so much obvious need for improvement, misdirected research efforts are something the industry can ill afford.

We should stress that we are not speaking out against a reasonable proportion of relatively undirected basic research. Studies such as those reviewed by Peter House and David Jones repeatedly emphasize that the long-term health of our economy demands a continuing effort in basic research. These studies also establish the basis for the persuasive argument that the federal government should take primary responsibility for supporting basic research and encouraging dissemination of the findings.[61]

RETRIEVING TECHNICAL INFORMATION

Historically, information about new technology has been disseminated through journal papers, reports, patents, and word of mouth. The recent technology and information explosion has caused the number of journal articles, reports, and patents to multiply to a point where it is unlikely that an individual can maintain an awareness of the state of the art of a subject area without the use of advanced information retrieval technology. For example, there are over 2000 separate and specialized technical data bases in the United States alone. Many of these data bases incorporate computerized search and retrieval capabilities. Some of the larger data bases have over one million entries each. A working knowledge of the technology, products, and processes of technical information retrieval is essential to individuals in management, production, marketing, development and/or research. Yet, there are many indications that few maritime personnel have the knowledge or the skills to enable them to make use of the existing information and data banks.

For example, engineers new to the maritime field face predictable problems in adjusting. One of these problems is securing the special types of information needed to design for the ocean environment. In a 1975 National Research Council panel report, the largest deficiency found among ocean engineers was their lack of awareness of existing sources of information. There are, in fact, information and data retrieval systems that are specifically designed to meet the ocean engineer's needs; yet, ocean engineers are largely unaware of them. Those that are aware of them are unsure about what data and information they contain or how to make efficient use of the material. "Even the largest, oldest, most versatile, or most automated systems are completely foreign to many prominent practicing ocean engineers."[98]

Since the free flow of information is so critical to the innovation process, some means of helping personnel in the maritime industry learn the techniques and skills required for technical information retrieval is needed. Prevailing educational curricula do not seem adequate to do this.

COMMUNICATION AND INFORMATION EXCHANGE

Before examining the various mechanisms for exchanging information about new research, new technology, and innovations in the maritime industry, it is wise to examine what exactly is to be communicated. As was mentioned in the preceding section, researchers often report their findings in a language that is not always intelligible to the rest of the world. Consequently, it is necessary to be concerned not only with the availability of research and technical information, but with the translation or transformation of that information into a form that can be used by industry. Technical information can be translated for industry indirectly (through the written word, lectures, via consultation, etc.) or directly (through job rotation, job training, demonstration of a new technique or device, etc.).

The number of potential avenues for exchanging information about new technologies and innovations in the maritime industry is virtually limitless. Worldwide, information is exchanged through educational centers; multinational companies; trade journals; international civil cooperative agreements; and through mutual defense organizations, such as the North Atlantic Treaty Organization. Nationally, communication can occur between government and industry, on an inter-industry basis, and on an intra-industry basis.

One of the keys to making use of these avenues to stimulate innovation and technology transfer is to identify the various mechanisms that can transmit technical information. One such mechanism is the written word. Periodic newsletters, abstracting services, and trade journals all provide a readily available means of information exchange. There are a number of these serving the maritime industry, including the Maritime Research Information Service (MRIS), managed by the National Research Council; MaraTech, distributed by MarAd; and Fact Sheet, distributed by the U.S. Navy. These and many other sources are readily available but are apparently little used by industry personnel.

People can also serve as an effective mechanism for information exchange. This process was illustrated in a federal government intern program that placed engineers and scientists from the airframe industry in both government and private sector laboratories.[3] More typically, when graduate students complete their formal education and go to work, they take with them new found knowledge often that they have helped create, and that may be more advanced than that of their colleagues who graduated in earlier years. The most common, and possibly most effective, means of people/information transfer is the technical forum.

Many studies document the need for properly coupling the technology and the market to produce a successful innovation.[61 94 148] One way to obtain such an alliance is to have the potential user of the innovation participate in the early research and planning stage of production. The success of this approach has been demonstrated by Stanford Research Institute. Under contract to NASA, they were able to use this method to encourage the private sector to use new space technologies.[148]

Finally, as was noted in Chapter V, linkers often serve a critical function in accelerating the rate of technological change. Linkers serve to connect new technologies with potential adopters. This function can be carried out on an ad hoc or semi-institutional basis, or it can be accepted as a formal responsibility. For example, the program managers that direct the research and development projects for the National Shipbuilding Research Program are becoming known throughout the shipbuilding industry as sources of information about new technology. They report that they often receive inquiries about a variety of technological advances that may or may not be directly related to the projects for which they are responsible. Thus, the program managers, who have accepted direct responsibility for disseminating information about their specific projects (institutionalized linker responsibility), are gradually assuming broader ad hoc or semi-institutionalized linker functions.

Many industries have made profitable use of formalized, third-party information exchange mechanisms to improve technology transfer. An obvious example is the federally sponsored Agricultural Extension Service. The prime responsibilities of this service are to disseminate information about agricultural innovations and to encourage farmers to adopt them. Such a model could, of course, be adapted to serve the maritime industry. The Sea Grant program may one day be equally effective in serving the maritime industry.

However, the final responsibility for improving information flow rests squarely upon industry. Companies that set a priority on the acquisition of information about technological advances are bound to be ahead of their competitors in learning about potentially useful innovations.

The various means of information exchange involve differing degrees of translation or interpretation from science, to technology, to application. A cost effectiveness judgment is required in the selection. Because most effective technology transfers require human interpretation, these transfers are likely to be the most expense.

CONCLUSIONS

- The exchange of information and a supporting environment for using this information are crucial to the innovation process.
- To make use of the large number of potentially useful and profitable innovations available, the maritime industry must first solve the problems related to exchange and dissemination of information.
- Quid-pro-quo exchanges of information with other leading maritime nations can benefit the U.S. maritime industry. When exchanges can be arranged with nations offering information comparable to that offered by the United States, both nations will profit.
- New research findings and new technological advances are apt to be ignored unless the potential user perceives a need for them.

- Many engineers, production personnel, and managers in the maritime industry are both unaware of the various sources of technical information that are available and are inexperienced in retrieving information. Opportunities for innovation are lost because of this lack of awareness.

- For innovation to go forward, there is a need for proper coupling of new technology and prospective market. One way of accomplishing this is to have the potential user of a technological advance participate in the early planning and research stages of the technology.

- Information exchange and the transfer of technologies and innovations will be expedited if engineers, technical personnel, and managers are introduced early to the benefits and uses of information networks and information retrieval systems. This exposure could be accomplished by inclusion of courses in these areas as a part of the standard university curriculum.

CHAPTER VII

RECOMMENDATIONS

As a committee, we accepted the premise that innovation and the consequent technological improvement in the U.S. maritime industry are crucial to the survival of the industry as a whole, as well as essential to the fulfillment of the purposes of the United States and of the industry. Accordingly, we examined the factors that influence the innovation process and concluded that the rate and quality of innovation in the industry could be greatly improved. Because the economic factors seemed to be the dominant influences, we concentrated on identifying opportunities to adjust these factors and make the climate more favorable for innovation and technological change. We also explored methods of improving the actual process of innovation within the industry, with particular emphasis on the adoption, implementation, and diffusion stages.

The recommendations that follow are derived directly from our conclusions. These conclusions, in turn, were derived from the analyses of the factors that affect innovation as outlined in the body of the report. Recommendations have been grouped under four headings: Finance and Economics; Personnel and Institutions; Research and Development; and Information and Education.

FINANCE AND ECONOMICS

In general, profit potential dominates the planning goals of industry decision makers. Therefore, we have accorded first priority to those recommendations that will either strengthen the competitive position of companies willing to undertake innovation or technological change, reduce the need for federal support, provide sufficient financial protection for companies willing to incur the risk of innovation, or encourage the federal government to share and/or assume financial risk in innovative ventures.

- We recommend that the Maritime Administration, in cooperation with industry, explore a variety of indirect subsidy and/or tax benefit arrangements that could serve to stimulate innovation in the maritime industry.

- We recommend that industry and the Maritime Administration cooperate to explore the development of insurance programs to encourage the introduction of new technology. If required, new legislation should be developed that would assist companies willing to introduce high-cost, high-risk technologies by insuring them against downtime and/or catastrophic loss. To the extent that reasonable coverage is found to be unavailable in the commercial insurance market, such legislation should include provisions for insuring U.S.-flag shipowners against loss of operating revenue that may result from the failure of innovative features during the trial period and during the initial period of regular operation.

- We recommend that the Maritime Administration periodically contract for building innovative merchant ships on government account. Such government-owned ships should be built to demonstrate the technical, institutional, and economic feasibility of applying research results and/or new technologies. Such ships should be suitable for resale or charter to U.S.-flag operators. Government construction of such ships is not without precedent.

- We recommend that the Military Sealift Command (MSC) undertake, as part of its mission, the adoption of innovations and new technologies on MSC ships. Such a shift in MSC policy should be made with full recognition given to the probability that a portion of the innovative features will fail and that one or more MSC ships may be put out of service for some time.

- We recommend that the Maritime Administration explore alternatives for developing a cost-sharing and/or loan-financing system to underwrite innovation. The aim should be to develop and implement a cooperative industry/government revolving fund to defray the introduction costs associated with innovation. Such a program would be particularly useful in encouraging innovations requiring major capital financing. Similar systems are currently used by the United Kingdom and other nations to foster their maritime industries.

- We recommend that the Maritime Administration and the industry work together to examine the appropriateness of special tax credits for innovators, as well as modifications in the current depreciation allowance structure, aimed at full recovery of current or replacement value rather than initial cost. Such a system might be similar to the tax deferred reserve fund allowed for ship construction that was established by the Merchant Marine Act of 1936 and amended in 1970.

- We recommend that the Federal Maritime Commission and the Interstate Commerce Commission work with ship operators engaged in domestic trade to seek ways of increasing the flexibility of the designated period of cost recovery for operators, as well as the designated period of retained profits resulting from innovations, before freight rate reductions are put into effect to allocate the benefits to shippers.

PEOPLE AND INSTITUTIONS

People and institutional factors also affect innovation. We stressed the need to achieve social equity and the need to assure the cooperation of labor when innovation is undertaken. The recommendations in this section are designed to achieve these purposes.

- We recommend that managers and labor leaders work closely together to improve employment opportunities and labor productivity and to institute training and retraining to enable workers, including displaced workers, to develop new skills and trades.

- We recommend that management and government regard the human costs of adjustment to new technology as part of the cost of installing such technology. Specifically, we recommend that industry adopt procedures that will provide sufficient advance notice so that labor and management can prepare adjustment procedures to assure equitable job and income security for affected workers.

- We recommend that the Maritime Administration and the Society of Naval Architects and Marine Engineers cosponsor research and development programs in all segments of the maritime industry. The existing National Shipbuilding Research Program could serve as a model. In particular, such programs are needed in the shipowner/operator segment of the industry and the materiel-supplier/ship-chandlery segment of the industry.

- We recommend that the Maritime Administration and other appropriate government agencies establish a periodic, routine policy review procedure for examining federal constraints on the introduction of new technology and techniques. The Maritime Administration should periodically petition Congress and/or the executive branch of the federal government to modify or remove those constraints found to be unnecessary.

RESEARCH AND DEVELOPMENT

Most new technology results from successful research and development projects. Even technology that has been borrowed from other industries or other nations may require some additional research or, at the very least, some pilot testing and demonstration before it can be adopted by the U.S. maritime industry. Yet, investment in research by the U.S. maritime industry is sorely inadequate when compared to what is considered a prudent level of investment by other U.S. industries or foreign maritime industries. Since research is integral to the innovation process, we have generated recommendations for improving the climate for and support of U.S. maritime research.

- We recommend that both industry and government increase their investment in U.S. maritime research and development projects and programs. The greatest increase in funding should be generated within each company through private enterprise investment, but an increase in the level of funding provided by the Maritime Administration and other government programs is needed as well.

- We recommend that the Maritime Administration, together with other institutions and groups in the maritime community, continue and expand opportunities for dialogue and consultation on establishing appropriate priorities for federally funded research and development efforts.

- We recommend that, despite the current economic situation, the Maritime Administration, the U.S. Coast Guard, and other federal agencies be encouraged to allocate an increased share of their research dollars to basic research leading directly to the development of fundamental technology for the maritime industry. Such research is needed to ensure the continued, long-term enrichment of the technological content of innovations.

- We recommend that, in addition to basic research, funds be allocated to support research in the areas of improving methods of adopting, implementing, and embedding new technologies and new techniques, as well as improving methods of information exchange and dissemination.

INFORMATION AND EDUCATION

The rate of innovation in the U.S. maritime industry is, at least in part, dependent on the rate and quality of information exchange and information dissemination. In the recent past, the United States has witnessed an explosion in the sheer quantity of available technological information, as well as a rapid growth in advanced methods of information storage and retrieval. Our recommendations are aimed at improving the information flow within the maritime industry and providing increased educational opportunities for industry personnel.

- We recommend that the Society of Naval Architects and Marine Engineers and other maritime-related professional organizations take the lead in promoting the development of courses, seminars, and/or workshops, on the availability of information retrieval systems, including the technology, products, and processes of the systems. Such courses would be offered by colleges and universities engaged in teaching maritime management, production, and research and development personnel.

- We recommend that the Maritime Administration, with the support of the industry, expand its leadership role in improving information exchange within the maritime community. Specifically, we recommend that the Maritime Administration establish a center for the exchange of technological information. Such a center could serve as a focal point for efforts to evaluate industry needs, stimulate innovation, transfer technology, and develop forms of inter-industry cooperation. The center could serve as a technology clearinghouse and be staffed with industry technical coordinators.

- We recommend that individual enterprises appoint at least one competent person to serve as an information liaison agent (linker, gatekeeper) to search for and disseminate new approaches and/or technology that will help the enterprise become more effective and competitive. The liaison agent also could function as a continuing source of information about the needs and problems of the enterprise that are amenable to technological or innovative solution. In this role, the liaison agent would have ready access to individuals, agencies, and institutions engaged in research.

- We recommend that each maritime trade association, such as the Shipbuilders Council of America, the American Institute of Merchant Shipping, the Committee of American Ship Operators, the American Association of Port Authorities, and the Council on American Flag Shipping, appoint at least one competent individual to serve as an information liaison agent. The liaison agent within these organizations should work to increase the flow of technological information among the various memberships. In particular, the liaison agent could expedite the flow of information about new technologies to potential users. In addition, each liaison agent could perform a feedback function by identifying the research needs and problems of the particular constituency.

- We recommend that maritime trade associations, the Maritime Administration, the U.S. Navy, and the U.S. Coast Guard develop special programs to increase public understanding of the value of commercial shipping to the national welfare.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Innovation in the Maritime Industry		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Committee on Innovation and Technology Transfer in the Maritime Industry		8. CONTRACT OR GRANT NUMBER(s) N00014-75-C-0711
9. PERFORMING ORGANIZATION NAME AND ADDRESS Maritime Transportation Research Board, National Academy of Sciences/National Research Council 2101 Constitution Ave., NW, Washington, DC 20418		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NA
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research, Code 434 Department of the Navy Arlington, VA 22217		12. REPORT DATE Qctober 1979
		13. NUMBER OF PAGES 92
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution of this report is unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Financial support provided by the Departments of Commerce, Defense, and Transportation.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Innovation, Maritime
Innovation Barriers, Maritime
Innovation Incentives, Maritime

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The report discusses factors that act as either incentives or deterrents to the process of innovation and suggests changes to be made to improve the climate for generating, transferring, and absorbing new technology and new practices, Report includes a discussion of the innovation process and an examination of the environment for innovation as well as economic factors and the people and information exchange required for successful innovation within the maritime industry. The text includes examples of successes and failures drawn from the case studies contained in the report Appendix which was published separately.

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