

Fundamentals of ship maintenance and repair for future marine engineers

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Abstract

This presentation is intended to emphasize the importance of teaching the subjects related to ship engineering operations, and specifically ship maintenance and repair (M&R), to analyze the existing practices in IAMU member institutions, and to offer practical recommendations. Although the share of maintenance and repair in the cost of ship operation is substantially lower than, for instance, fuel and crew expenses, its cumulative impact is quite substantial. Besides the direct costs, this impact includes related down time, that reduces revenues, delays causing lost opportunity and more revenue loss, insufficient quality of repairs, affecting ship performance, and causing emergency repairs and down time. The fundamentals of ship maintenance and repair are examined from the standpoint of the theoretical and practical knowledge required. The STCW and other requirements are evaluated. The importance and expected outcomes of teaching the subject is discussed as a way of enhancing the knowledge and providing a needed edge in landing a better sailing job, and also a possible future job ashore, as a port engineer, or as an experienced professional in a shipyard and other repair enterprise, as well as in engineering companies. Various approaches to the problem are discussed with an accent on the limitations of the already overloaded four-year curriculum

Keywords

Marine engineering program, ship maintenance and repair (M&R), components of engineering curriculum

Introduction

Despite the efforts of the IMO and the Maritime Community, the existing curricula in many maritime schools does not totally meet the maritime industry's need for specialists with integrated knowledge of specific engineering and operational disciplines. One of the principal concerns is a relatively low readiness of the graduates to assume engineering positions ashore: at shipyards,

in engineering companies, or shipowner's engineering departments. Maintenance and repair (M&R) is the program component that varies quite substantially in its scope and content. Many licensed marine engineers, who are starting their careers with shipping companies, might soon perform port engineering functions, coordinating maintenance and repairs of assigned ships. Today's licensed marine engineering program should be designed to provide a midshipman with a solid base in mathematics and science, humanities, fundamental engineering science and specific marine engineering disciplines along with knowledge in the management of ship maintenance and repair.

Keeping in mind that the demand for competent seafarers will grow in the years to come, enhanced education and training are vital in meeting growing demands and expectations of the maritime industry. The underlying reason for the curricula development, or rather enhancement, is the need for system approach to the maritime education. The engineering sector of the maritime industry embraces not only the ships to be operated, but also the shipyards and various ship repair facilities, engineering companies and ship designers, equipment manufacturers, engineering departments of shipping companies, etc. The ideal education for the high mobility workforce should provide enough knowledge and skills for a comparatively comfortable adaptation in other areas of the maritime system.

1 Operational impact of maintenance and repair (M&R)

Mission, design type and specific features, ship's registry and flag - all these and some other issues affect the operational cost of a ship. The crew cost differs depending on the ship's complement and on the salary level. Obviously, for open registry ships the crew cost is substantially lower than for the American Flag ships. The same is true for the ships with automated engine rooms and correspondingly reduced crews. Although the annual cost of fuel and lube oil depends primarily upon the type and capacity of the propulsion plant and auxiliary machinery, its share in the total operational cost varies substantially reaching the maximum for the reduced crew ships, especially in the case of extra large tankers and cargo carriers. Using the example of an American registry large cargo carrier, the fuel cost amounts to 25-35% and it increases to 45-55% for the open registry ship.

Maintenance and repair expenses - the third major component of the operational cost - is very low, about 5-7% of the total cost, when a new ship enters the operation. However, it goes rapidly up to 15-20%, as the ship ages. After the midlife has been reached, the maintenance and repair portion of operational expenses might reach 25-30% and even more. As it has been noted earlier, although the share of M&R in the cost of ship operations is comparatively low, its cumulative impact appears to be quite significant. In the following table, an attempt is made to assemble all significant factors related to

ship maintenance and repair, and their impact on ship operations, especially when the M&R management is insufficient.

Table 1. Impact of M&R on economics of ship operations

No	M&R Factors	Impact on Economic Results of Ship Operations
1	M&R Cost	- actual cost of M&R, that causes reduction of operational profit - cost of deviation required to deliver a ship to a shipyard outside of the normal area of operation
2	M&R Duration	- down time as a result of failure or voyage repairs - non-operational time while in a shipyard - deviation time for bringing a ship to a remote shipyard
3	M&R Quality	- ship's down time due to failures and emergency repairs - reduced ship's equipment performance and associated increased operating costs and reduced revenues
4	Safety	- crew casualties and associated down time and costs - serious occupational injuries and corresponding law suites, legal costs and substantial reward payments
5	Environmental	- fines and penalties for sea and air pollution - crew productivity reduction as a result of health problems and job dissatisfaction
6	Marketing	- possible cargo damages due to ship failures and down time - late cargo delivery for the same reason and the corresponding penalties and even loss of a customer - failure down time causing lost opportunity and possibly a loss of a customer

2 Reasons for teaching ship maintenance and repair

The list of management subjects, related to ship maintenance and repair, with which the marine professionals are dealing, is practically endless. Huge resources are being spent to carry out maintenance procedures traditionally, while modern computer based maintenance system can save a lot of labor and material resources. The crew members should be taught these modern management techniques.

Even more improvement might be expected when the reliability-centered maintenance is introduced. The latter is defined as a systematic approach to develop a focused, effective, and cost efficient preventive maintenance program for such a complicated system, as a ship. It can be accomplished using a structured decision tree, which leads to a selection of the most applicable preventive maintenance tasks, and this way saves substantial resources. This approach is based on a comprehensive theoretical foundation, which includes good understanding of the reliability fundamentals coupled with the familiarity with probability and statistics applications.

Another important area which requires proper college education is the problem of spares on board. The ancient wisdom dictates to the chief engineer to

have as many spares as possible on board. On the other hand, the economic consideration calls for the minimization of inventory. Today's engineering graduates are not equipped with the modern methods of inventory management. As a result, many ships that are ready to be scrapped, carry on board millions of dollars worth of inventory; for example, one or two spare propellers, anchors, sections of the propulsion shaft, variety of valves, pipes, fittings which can hardly be sold for the face value, when the ship is retired. Therefore, when adding spares to the ship's inventory, the engineers should be guided not only by technical consideration, but also by economic reasons. For instance, the cost of having certain spare part on board should be compared with possible economic losses if it is delivered only when needed. And in many cases, this decision should be made on board by the ship's engineer.

Lack of a proper justification of maintenance and repair actions should be blamed for some negative results, when, for instance, choosing the best yard to carry ship repairs. New on the market repair facilities are appearing on the map: in China, Poland, India, Brazil, etc. More and more shipowners bring their aging ships into remote yards with a substantial deviation from the normal area of trading. A lot of mistakes have been made due to insufficient, or simply inexistent management justification. Most of the shipowners concentrate on the cost savings from the repairs leaving other variables not fully investigated: losses due to deviation, possible increased duration of repairs, problems with repair quality, etc. Lengthy delays and poor quality might add to the negative results of the endeavor. For the American flag ships an additional huge expense is added - custom dues on the cost of repairs done.

Another area where sufficient M&R background can save a lot of money is the decision regarding the scope of upcoming shipyard repairs. How much repairs to request from the yard? What is less expensive in a long run: to include a certain item in the repair specification, to carry it next time, or to do it onboard by the crew members or a riding team? All these questions represent typical decision making situations when a properly laid-out judgment is needed.

Organization and management of ship repairs in a shipyard is one more subject, where appropriate management training is needed. After the ship has been delivered to the shipyard, the primary concern of the owner's representative is the constant changes of the work scope, which require making immediate decision. First of all, the necessity of the change should be technically and economically justified by comparing losses and benefits for two options: the original work scope and the change.

Another important subject for consideration by the shipowner is the quality of repairs. The shipowner does not have much leverage over the shipyard, when it concerns the quality. However, the increased presence of the qualified owner representatives at the yard is very effective in controlling it. The fact that more monitoring is done allows to uncover the shipyard defects on time and to prevent substantial financial losses. The shipowner might affect the quality of repairs also by supplying certain materials and equipment. It is a common

practice for the shipyard to acquire most of material resources needed for repairs. And the owners are normally in agreement with this practice. One of the main reasons is that this way many possible shipyard's claims to the owner for the cost adjustment due to alleged owner-caused delay might be eliminated. However, when the economic analysis indicates that better materials, or painting schedule, or equipment will bring substantial financial benefit in operations, the shipowner might request the yard either to supply those better materials and equipment for an additional cost, or to accept the owners supply.

An important reason for an enhanced training is the growing need to make the marine engineering program more attractive for prospective cadets. Nowadays, when a young man or woman is considering a maritime profession, a couple of questions might pop up: What will happen to me if in a few years after graduation I would not be able or would not want to sail any more? Will I be prepared for a shoreside job? Additional industry oriented knowledge offered at school might amplify the career path ashore. This consideration might appear a decisive one in choosing the profession. If the question of a possible career change appears in the future, enhanced training helps to get a positive answer. These days, when the romantic attractiveness of the marine engineering profession is getting weaker, the maritime colleges have to demonstrate to the prospective cadets, that they are moving in the same directions as most of the regular engineering colleges; that is, in the direction of an increased scope of the industrial management component of the program.

Yet another important objective for improvement of the program exists: to help the graduates to land a better first job. Added skills will put the graduates ahead of the competition equipped only with traditional curriculum. The statistics of the USMMA shows that a part of our engineering graduates never sail, and a large percent of those who find sailing jobs after school, eventually go ashore and assume various engineering positions. Enhanced knowledge of current industry practices appears even more valuable for shoreside positions. Especially, after a few years, when the former cadet gains certain experience and is ready to assume a management position.

And finally, the subject of the program STCW certification: the comprehensive international certification of the maritime schools and of their graduates which has been initiated by IMO, includes certain competence in maintenance and repair to be obtained by each graduate. The following table is an excerpt from the STCW Code related to the subject.

Table 2. M&R in STCW Code

Competence Code	Knowledge, understanding and proficiency
Function 4: Maintenance and repair	
4.1	Marine systems Safety and emergency procedures Fundamentals of maintenance and repair

An enhanced M&R education is required for the lower level decision making. As an example, we might note the crew reduction efforts, which are still among the most popular ways of cutting operational cost. On one side, this is a technical problem: the ship should be prepared and capable to have the crew reduced. On the other side, this decision brings up multiple management problems and questions, and there is no guarantee that all crews are ready to operate under reduced conditions. First of all, crew reduction changes the functions and responsibilities of crew members, and the necessity to increase efficiency of every crew member becomes vital for the success of the program. But in order to achieve it, crew members should be armed with knowledge of this efficient methods.

A lot of functional changes are happening in the area of shoreside engineering support. While it is true that the number of shipboard engineers is decreasing due to automation, the total number of engineers required to operate a ship has not been dropping accordingly. Certain functions of the reduced crew should be performed now by engineers ashore, especially port engineers and repair engineers. At the same time, the overall performance of the engineering personnel at headquarters, as well as, the remaining crew members should improve. In practice, every port engineer normally handles three or four large ships with manned engine rooms; when dealing with unmanned engine rooms the number drops to two or three ships. Moreover, engine room automation leads to increased volume of shipyard repairs. In order to properly supervise these ships an extensive knowledge in management of ship maintenance and repair is required. In addition, ships are becoming more complex and more automated. Chief Engineers, First Engineers, and Port Engineers are increasingly responsible for managing a wide range of activities related to ship operation, repair and maintenance, and would benefit from additional management education. The principal tasks related to the ship's operation and at the same time dependent on the performance of the Engineering Department are reduction of the cost of fuel, and of repair and maintenance. Without giving the crew members basic knowledge, which will allow them to take proper actions in this area, it is hard to expect the most efficient decisions.

3 Additional knowledge required

Engineering programs are normally more condensed, and a common believe is that there is not enough time for anything else but the established curriculum. The average length of a program, which leads to the Third Assistant (or just Forth Engineer) license, is four years, including about a year of sailing. However, there are three- year programs, on one side, and five-plus-year programs, on the other side, like in Russia and Ukraine. The distribution of time among the components of a program and the list of academic courses vary quite substantially from country to country, and even among different schools of the same country.

The author’s analysis of the M&R related subjects in the existing marine engineering programs shows the following maintenance-related component in the curricula of over 20 maritime educational institutions (see the chart below). Obviously, the longer programs allow for an increased scope of the M&R component.

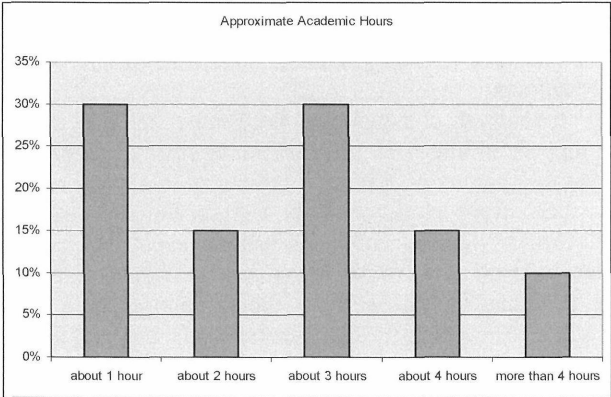


Figure 1. M&R subjects in the marine engineering programs.

What additional maintenance management knowledge is needed and what is the relative importance of certain subjects to be considered? The discussion below reflects the author's thinking and an attempt to prioritize various areas of multi-functional education relative to a marine engineering curricula.

The very first subject to be considered is a general course in marine engineering management, which might be a portion of the introductory to profession package. As to the special subjects to be introduced, the highest priority should be given to a series of courses in Ship Engineering Operations, which includes ship maintenance and repair, materials, manufacturing processes, basics of operation of shipyards and ship repair facilities. These courses

augmented with a two-month internship in a shipyard or a similar facility will provide a solid foundation for a possible shoreside industrial employment. The Table 3 outlines the principal content of the Ship Engineering Operations course.

Table 3. Components of ENGINEERING SHIP OPERATIONS Course

<i>No</i>	<i>Course Components</i>
<i>1</i>	<i>Management of Engineering Operations</i>
<i>2</i>	<i>Maintenance and Inventory Control Management</i>
<i>3</i>	<i>Ship Surveys and Inspections</i>
<i>4</i>	<i>Ship Repair and Drydocking</i>
<i>5</i>	<i>Basics of Ship Repair Facility Operation</i>
<i>6</i>	<i>Safety of Ship Engineering Operations and ISM</i>
<i>7</i>	<i>Shipboard Economics and Cost Control</i>

4 Methods of enhanced training

The most popular and, possibly, the easiest way of amending the curriculum is to develop special courses. Most schools have, at least, one mandatory operations management course. Although, it provides certain fundamentals, it does not add substantially to the practical applications of the theory in the maritime industry. It is well known that any addition to existing programs is almost impossible, unless they are offered as electives or overload.

Another way of inserting some M&R subjects into the curriculum is by developing new or modernizing existing course projects and independent studies. These projects should be prepared by the cadets either during their sea service and apprenticeship period, or during the regular academic year. It might be a design project which includes justification of the chosen alternative, or development of the project management plan, or analysis of existing systems and equipment and evaluation of possible changes, etc. At some schools, where the in-class period exceeds three years (in Russia, Ukraine, China, for example), a special diploma project or thesis is being prepared during almost the entire semester. It appears to be a very useful tool of management training, and is somewhat analogous to the senior thesis required at many of the best colleges in the US.

A comprehensive capstone design project is developed by the seniors of the specialized Marine Engineering Management Program at the US Merchant Marine Academy. One of the principal projects, which a team of four midshipmen is working on during the entire senior year, is entitled SHIP OVERHAUL PROJECT. The team uses a repair specification obtained during the internship or provided by the Faculty Advisor. The principal modules of the

project are shown in the Table 4. After completing the project a graduate feels very comfortable, when offered a job as an assistant port engineer, or as a project engineer at a shipyard.

Table 4. Typical content of a senior capstone design project

No	Capstone Project Modules and Tasks
1	<p><i>Development of a bidding package</i></p> <p>1.1. Preparing a draft repair specification 1.2. Estimating cost and setting a budget 1.3. Finalizing repair specification 1.4. Approximating repair duration 1.5. Developing request for proposal</p>
2	<p><i>Economic evaluation and justification</i></p> <p>2.1. Economic justification of overhaul vs. scrapping 2.2. Economic evaluation of selection of a shipyard 2.3. Economic justification of overhaul</p>
3	<p><i>Project management strategy</i></p> <p>3.1. Selecting schedule activities 3.2. Estimating schedule activity durations 3.3. Developing a draft schedule 3.5. Optimizing schedule 3.6. Balancing workforce 3.7. Developing final schedule</p>
4	<p><i>Modernization proposals</i></p> <p>4.1. Selecting proposals 4.2. Preliminary design 4.3. Economic evaluation of proposals 4.5. Design calculations and sketches 4.6. Final drawings and diagrams</p>
5	<p><i>Design of production processes</i></p> <p>5.1. Breaking down into operations 5.2. Production procedures 5.3. Calculating operation characteristics 5.4. Identifying time rate</p>
6	<p><i>Shipyard capacity analysis</i></p> <p>6.1. Shipyard master production plan 6.2. Workforce requirements 6.3. Capacity of principal facilities 6.4. Shipyard modernization proposals</p>

An internship at a shipyard or a similar facility should be considered a vital component of a multi-functional program. All midshipmen enrolled into the Marine Engineering Management Major at the US Merchant Marine Academy

are required to work two months in a real production environment. Most of them either assist Project Manager at the shipyard, or work with a Port Engineer, who is supervising an overhaul of his ship. The following is a short list of the subjects the interns are required to learn or at least become familiar with:

- Shipyard preparations to performing the contract job
- Engineering support services
- Planning and scheduling of a contract
- Management of construction and repair program and of individual projects
- Organization and production methods in ship repair and overhaul
- Work outsourcing in repair and construction projects
- Principal capacities of the shipyard
- Material management:
- Modern ship repair and construction methods and procedures
- Quality control, testing and trials

An important component of the maritime educational system in some countries is post-graduation training: after a certain period of sea service, the officer returns to school for additional instructions in order to raise the certification level. In our opinion, this is a very efficient way of improving the qualification of officers by introducing them to all the latest changes and developments in maritime practice. However, obvious financial and organizational barriers do not allow this training to become a mandatory system, which it definitely deserves to be. The experience of France, Belgium, Indonesia, Israel, Russia and other countries supports this conclusion. A special decision of an international body is long awaited in order to set unified requirements for promotion of marine officers.

Until these unified requirements have been set, many schools are offering various advanced courses to former graduates, not necessarily of their own school. These are either refresher and retraining programs, for instance, from steam to diesel, or special training based on new regulations and changed work conditions. There are also various courses related to new equipment and technology. That is when a special attention should be given to the M&R management training. Moreover, some courses might be geared to a relatively narrow area, like management of shipyard repairs, methods of reliability-centered maintenance, etc. Incidentally, many companies are sending their engineers to regular universities for management training on the continuing education basis.

5 Conclusion

A variety of tasks being performed by the engineering graduates of the maritime academies, who are either sailing or working ashore, require multi-functional education related not only to ship operations, but in a great degree also to shoreside jobs. Therefore, the basic knowledge of shipyards and other manufacturing enterprises, as well as ability to manage ship maintenance and repair, should be included into the curriculum of the maritime schools on a substantially higher level and scope, than it is done now. However, providing that the engineering license remains the first priority of any program, this task puts a strenuous time limitations.

Therefore, the endless list of industrial management subjects and topics, which are useful for the cadets, should be prioritized. And the highest priority should be given to the subjects of ship engineering management and operations, optimization of ship maintenance and repair, repair project management, etc. Development and introduction of special courses in accordance with the priority list is the simplest and most widely used method of M&R training. However, due to time constraints in the program, these are mainly elective courses.

Industrial management training after graduation is quite popular in some countries, and should be further developed. It would be very helpful if a Maritime International Body develops uniform requirements to the engineering programs and also to the promotion of the engineering officers.

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