COMPUTERS, MAINTENANCE MANAGEMENT AND BENEFITS OF COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEMS IN THE MARINE INDUSTRY

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INTRODUCTION

Ship operators and owners have been typically slower to respond to and adopt new developments in technology as compared to those in most other industries. Most ships are run on traditional operational practices which have been in place for generations. When operating practices do change, the changes are driven either by regulatory requirements or by economic needs. Shipping, however, has come a long way from the days of its beginnings.

The shipping industry is unique in many ways and operates under circumstances in which no other industry does. A typical ocean-going ship is owned by a company based in one country, registered in another, managed by a company based in a third country, manned by citizens of yet another country, and carries cargoes belonging to someone of an entirely different nationality. Coordinating and managing activities on such a global scale is truly a daunting task. Under such circumstances, it is not hard to imagine why adoption of new technology is slow in shipping.

Intense competition among ship-owners and pressures from environmental groups and governments have forced ship-owners to change the way they do business. Modern-day communications and other technological developments, especially in the field of electronics, have been adopted by some ship-owners in an attempt to reduce operating costs, and at the same time, provide a better service to their customers. The past two decades have seen a surge of new developments in shipboard technology. Most ships today are fitted with satellite communication systems, electronic navigational aids, automated engine rooms, etc. . These developments have led to a reduced and more professional crew, and a safer, more environmentally friendly ship which is faster and more fuel efficient than ever before.

Because of the global nature of a ship's business and the many diverse ports a ship calls at, ships have traditionally carried on board spares for all their machinery and equipment and are usually equipped with spares for every conceivable nature of breakdown of machinery. While cost-cutting measures have been adopted in many ways on board ship, an area which has been neglected to a large extent is the shipboard maintenance management system and spares inventory system.

The purpose of this paper is to give a comprehensive look at shipboard computerized maintenance management systems. The paper is organized as follows. In the first chapter, an overview of the present use of computers and information technology in the marine industry is presented. In chapter two the fundamentals of the economics of shipping is explained. Here, the costs of shipping operations, the state of demand for shipping, the marine trade, and the subjects of ship's unavailability and its opportunity cost are discussed in detail. Chapter three gives a mathematical evaluation of the long term objectives of maintenance management, a brief description of reliability, and the evaluation of the different types of maintenance approaches. Chapter four highlights the reasons for implementing a computerized maintenance management system on board vessels. Chapter five elaborates on the different benefits resulting from the implementation of a Computerized Maintenance Management System, and evaluates the benefits in a tabulated format.

Before developing the above mentioned topics, it is essential that I mention my involvement in computerized maintenance management systems for the marine industry. For five years, I worked in the field of computerized condition monitoring and maintenance management. In this paper, I have drawn significantly on the experience and knowledge I gained during those five years, whether from employment training and experience, and from public information available from within the company or gained from reading industry literature.

CHAPTER 1: COMPUTERS ON SHIPS

The use of personal computers on board ships began towards the late 1980's. These were usually stand-alone-type computers and various types of software packages were commercially available for shipboard use. A typical comprehensive software package includes a computerized maintenance management system, vessel loading and stability data, provision system, and crew payroll. Microcomputers software packages prices usually range from $10,000 to $50,000 or more depending on the complexity of the system, while mainframe software can cost as much as $500,000 or more.

The use of planned maintenance systems and spares inventory systems has led to a tremendous cost saving to ship-owners. Ship-owners can now access any data relating to spares consumption on board. The purchasing procedure has been simplified by the computer's ability to draw up requisitions automatically at specified reorder points based on depletion levels. Computers also store data regarding the suppliers of a particular spare to the company in the past and their performance. This reduces the effort required to receive fresh quotations from suppliers every time a similar order has to be placed. The company can directly refer the supplier to the previous order and request a fresh quotation. The supplier's job also becomes easier because there is no need to repeat all relevant specifications every time an order is placed.

INFORMATION TECHNOLOGY AND ELECTRONIC DATA INTERCHANGE

The use of electronic data interchange to facilitate information technology on board ships is a recent phenomenon and is still in its developmental stage. An example of this system is the one used by Stolt Tankers[1]. Stolt uses commercially available software which contains a database of every piece of equipment and spare part that might be ordered. The Master or Chief Engineer creates a new requisition by selecting items from the database. The selections are registered as changes to the ship-based database. The changes are sent via satellite to the company's shore based database which is a copy of the ship's database. Changes to the shore based database are passed to the company's enterprise purchasing system where each requested item is automatically matched against a database of vendor contracts. Once a vendor receives an order, the goods are sent to the ship. Upon receipt of the goods, the ship creates a bar-code tag complete with storage information and an update to an inventory record on board ship and ashore, which in the form of data sent to the shore, triggers an electronic payment to the vendor.

Another similar system is that used by Stena Sealink[1]. The package named MASP manages both maintenance and spare parts. MASP is a completely decentralized computer system which provides the necessary information on what maintenance is required, when it should be carried out, and by whom. Simultaneously, it gives a precise picture of the stock of spare parts, its location, and when to re-order. The management ashore can retrieve or add to any of the information in MASP through Communication Master, the central communication module of the software and part of the integrated system. This transfers data via satellite, modem, VHF, or land

[1] Butchers, John. "Marine Management Benefits from Computerized Planning and Video." Marine Engineer's Review, October 1995.

based telephone from the ship to shore or vice versa. To ensure there are adequate spares on board for routine maintenance and repair, the company employs an in-house developed software package called SMARTS (Stock Management and Requisition Transfer System), which controls functions such as inquiry generation, stock control management and automatic replenishment to set levels, and budget monitoring.

CHAPTER 2: ECONOMICS OF SHIPPING

Shipping is the most important mode of transport of international trade accounting for about 90 percent of all international trade movements[2]. According to the Swedish Shipping Gazette, the total ton-miles by sea are more than twice the total ton-miles by road, railway, and air, put together. By 1987, the total international trade in tons was about seven times greater than in 1950. This corresponds to a rate of growth of 8 percent per annum[2]. The unit of measurement of volume of production or supply in shipping is the number of cubic ton-miles.

We can distinguish three main types of shipping activities:

1. Liner Services: Shipping lines maintaining regular services between specified ports according to schedules advertised well in advance. Liner services are carried out by conventional liners or by unit load vessels (e.g., container, RORO, or palletized vessels).

2. Shipping for hire: also called tramps. Traditionally used to be an all-purpose ship with the idea of maximizing the chances of getting a cargo in any port of the world. The shipping-for-hire services are carried out by specialized bulk carriers to take one or two types of cargo (e.g., ore and oil, carried by Ore-Bulk-Oil (OBO) ships).

3. Own shipping: company-owned or long-time charter ships which carried their goods. It is confined to specialized shipping activity, especially in the bulk-shipping market (e.g., oil, coal, metal ores).

[2] Jansson, J.O. and Shneerson, D. Liner Shipping Economics. Chapman and Hall Ltd., 1987, p. 3

2.1 DEMAND AND SUPPLY OF FREIGHT SHIPPING

Shipping services are not storable. If supply capacity exceeds demand the excess cannot be stored and sold when needed. There are considerable variations for shipping demand of which three reasons can be distinguished.

1. The unpredictable major contingencies, such as political upheavals, economic policy changes, or climate changes. For example the closure of the Suez Canal lead to an increase of 15 percent in tanker ton-miles due to the re-routing around Cape of Good Hope.
2. The large number of recurrent, such as strikes and other work stoppages, weather changes, production and tastes variations.
3. Predictable cyclical fluctuations, such as seasonality of agricultural products, peak oil shipments to Europe or North America in the winter.

2.2 STRUCTURE OF COSTS

Shipping costs are broken down into groups that relate directly to the actual management structure in the marine industry. Such groups of costs are crew costs, fuel costs, insurance costs, repair and maintenance costs, depreciation and interest on capital, cargo handling costs, and overheads.

In our discussion, we will only tackle costs affecting or affected by maintenance management. Factors that are related to the costs' structure will be mentioned but not discussed.

2.2.1 CREW COSTS

Crew costs are today one of the most important factors influencing the efficiency of shipping operations. It constitutes 15 to 25 percent of the vessel's operating expenses[3] and depends on the ship's size and the manning scale, on the nationality of the crew, and on pay conditions. The manning scale is the distribution of personnel per rank, profession, and skill on board a vessel. It is usually agreed upon between the marine industry and the mariners' unions, within norms set by the International Maritime Organization, a United Nations agency.

Engineering staff's pay conditions are directly related to the maintenance activity on board the vessel. Any maintenance activities taking place outside regular working hours are subject to overtime charges. Also, certain special maintenance activity arising from unusual emergencies under difficult or dangerous conditions would be subject to special work payments. Those costs can be better controlled when regular and special maintenance activities are monitored and managed using computerized maintenance management systems (CMMS).

Manning scales and nationality of the crew have direct relationship with the technical set up and automation of vessels. In countries with low manning scales, fleets tend to have a high degree of automation (e.g., Norwegian fleet) taking advantage of the situation to reduce labor costs. Countries with high manning scales (e.g., USA) and high pay scales would be better off using Computerized Maintenance Management Systems to reduce any overtime or special assignment costs.

[3] Chrzanowski, I. An Introduction to Shipping Economics. Fairplay Publications Ltd., 1985, p. 76

2.2.2 FUEL COSTS

Costs of fuel and lubricants represent 12 to 25 percent of the total operating costs[4]. They are determined by a number of factors such as the type and condition of the engine, type of fuel used, price of the fuel, and very importantly the speed of the vessel. Age and mechanical condition of the engines are very important elements influencing the level of fuel costs, as are the skills of the engineering staff and the management of maintenance. Also, the shape and condition of the vessel's hull affect fuel consumption.

2.2.3 REPAIRS AND MAINTENANCE COSTS

These costs account for 10 to 15 percent of the total operating costs[5]. There are several types of repairs and maintenance, some are completed based on a planned schedule (e.g., quadrennial and annual classification repairs and surveys), some are just corrective (upon breakdown or collision). Dry-docking, blasting, and painting are carried out on routine basis, between voyages. Nowadays, most maintenance chores are carried out by the sea-going crews, although the trend in crew-size reduction has shifted maintenance activities toward an increasingly automated mode of repair and maintenance management and constant alarm-based equipment monitoring.

Repairs and maintenance of older vessels cost more than new ones. That is true in the case of any mechanical vehicle. No age limits exists for scraping a vessel but after 10 to 15 years of operation, repair and maintenance costs tend to rise sharply[5]. However, experience shows that

[4] Chrzanowski, I. An Introduction to Shipping Economics. Fairplay Publications Ltd., 1985, p. 78
[5] Chrzanowski, I. An Introduction to Shipping Economics. Fairplay Publications Ltd., 1985, p. 78-79

ships that are properly maintained by competent crews and follow an adequate maintenance management system may be as successfully operated as newer ships.

2.2.4 INSURANCE COSTS

Cost of insurance accounts for 6 to 12 percent of the ships fixed costs[6]. Insurance costs are mostly affected by the actual value of the ship and the scope of the coverage. However, other factors such as the age and condition of the vessel, the maintenance system, the experience of the operator, and the aptitude of the crew do affect the pricing of the insurance. Recently, on a case by case basis, insurance companies have started allocating modest rebates to operators that have implemented computerized maintenance management systems on board their vessels.

2.3 SHIPPING OPERATIONS COSTS CLASSIFICATION

There are two categories of ship owners: those who own and operate their fleet and those who hire ship management companies to operate their vessels. For the purpose of our paper, we will use the term ship operator for ship owners who operate their fleet and for contracted ship managers. Costs borne by ship operators determines the price for shipping services (transport of goods, passengers, both commercial and military), or the funding necessary in the case of non profit oriented bodies such as government, para-government, or military organizations. Tariffs in liner shipping or charter rates are examples of price of shipping services. The price for shipping is not always solely based on costs. Other economic and non-economic factors could also affect the price of shipping such as competition, cartel pricing, or regulatory restrictions.

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[6] Chrzanowski, I. An Introduction to Shipping Economics. Fairplay Publications Ltd., 1985, p. 79

In general, costs are divided into fixed and variable costs. Shipping economists distinguish four major groups of costs: overheads, operating costs, voyage costs, and cargo costs.

Overheads are considered as fixed costs and are accounted for just as any other company or organization overhead expenses such as general management costs, marketing and advertising. These costs also include costs that are specific to the marine environment such as nautical, technical, and control of marine stores.

Operating costs that are specific to the vessel and are related to the maintenance of the ship in service are considered fixed costs. They include maintenance and repair, ship's deck and engine stores, surveys, insurance, and staff costs.

Voyage costs are usually considered as variable costs. They include fuel costs, port dues and charges, and agency expenses. In certain cases of liner shipping, vessels run on a scheduled service where ports of call and voyage distances do not vary. In these cases voyage costs would be considered fixed.

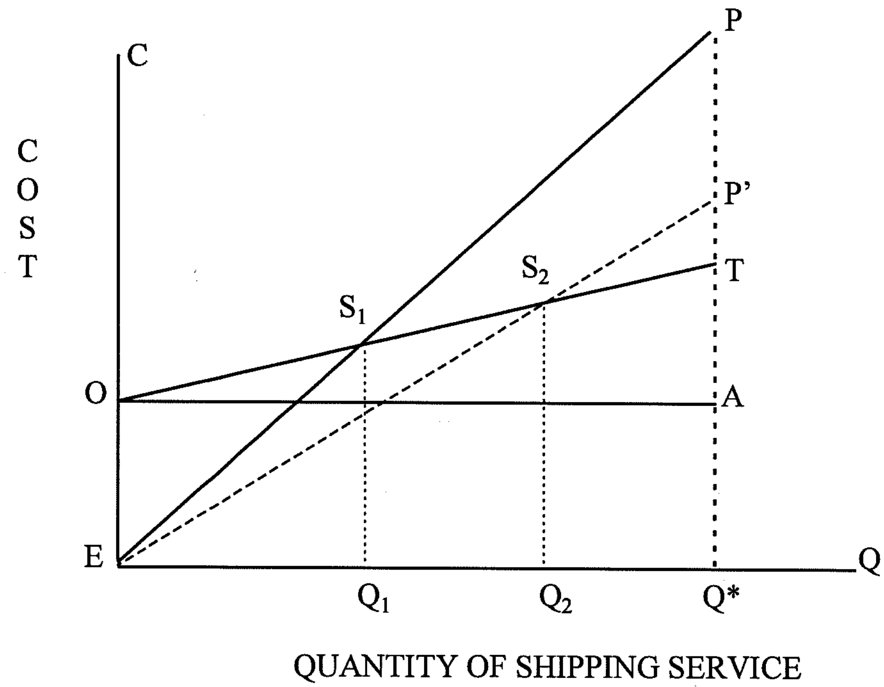
Cargo costs are typically variable costs that depend on the nature (e.g., passenger, dry cargo, oil) and the quantity of the cargo. They include cost of loading and discharge, or passenger's service costs.

For the purpose of our discussion the most important costs fall under operating expenses and voyage costs. Maintenance management systems affect or are affected by maintenance and repairs, ship's stores and inventory, surveys, insurance, staff costs, and fuel cost.

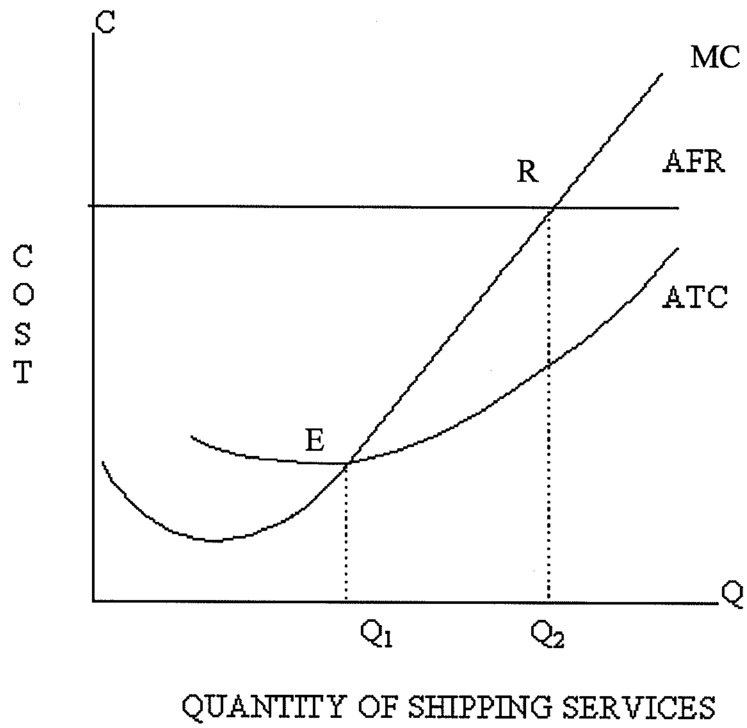
2.4 COST ANALYSIS

Ship economists base their analyses on total cost, average cost, marginal cost. They analyze these costs relatively to factors such as ship's size, voyage distance, speed, cargo carried, and determine their effects on shipping costs .

The following figure illustrates the relationships between fixed costs, variable costs, and revenue. Variable costs are proportional to the cargo tonnage and vary accordingly, bearing in mind that cargo handling costs and other variable costs are relative to the quantity of cargo transported. The costs and revenues' lines, and profit and losses areas are identified in the figure below. The fixed costs are represented by the line OA. The total costs are represented by the line OT and are the sum of Q*A (value of fixed costs) and AT (value of variable costs). The lines EP and EP' represent the revenues, while the points S_1 and S_2 represent the break-even points necessary to generate freight revenues which will be sufficient to cover total costs. In the initial case, the area ES_1O represents the loss, while S_1TP the corresponding profit, with Q_1 being the corresponding break-even quantity. When the revenue line is shifted from EP to EP' the break-even point will be S_2 and the profit will be considerably reduced to $S_2P'T$ while the quantity to be transported to cover the total cost must be Q_2 . The relationship between costs and revenues described in the figure is based on the assumption that freight rates are fixed, while in practice rates often vary. Shipping conferences and cartels could influence the rates, shifting the revenue line to the left and increasing profit.



Another cost is the marginal cost which is critical to a freight shipping operator. In the shipping context, marginal cost is the net increase in total cost when the production is increased by one ton or one ton-mile. Marginal cost as defined above is not a parameter that has direct effect on the subject of our study however, we believe that it is worth mentioning. In the figure below, ATC represents the average total cost curve, AFR represents the average freight revenue line, MC represents the marginal cost curve, and E represents the lowest product cost.

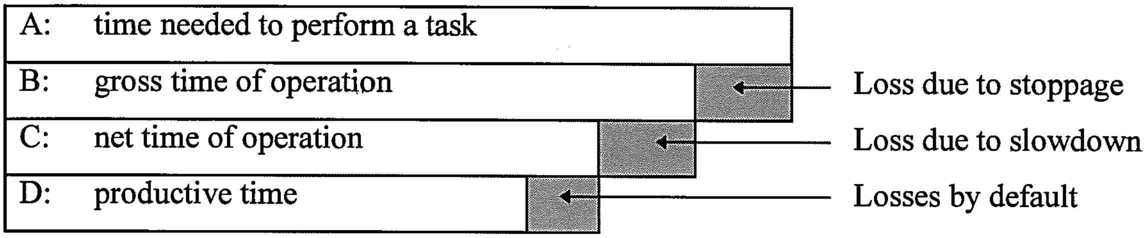


Freight operators tend to take on extra cargo even if they are subject to an increase in marginal costs above the AFR curve in order to keep their market share. Their expectation is that smaller and less financially sound operators will drop out of the competition which would drive the freight rates upward and consequently the AFR line above the MC curve.

The last type of cost is the opportunity cost, which is the relevant concept of cost for economic analysis. However, it is very difficult to measure opportunity costs, except when it is relevant in the economic evaluation of various alternatives of vessel employment other than, for example, lay-up, charter, or continuation of service. Relatively to our study, there is a relativel correlation between an adequate management of maintenance and the frequency and duration of lay-ups.

2.5 LOSSES DUE TO SHIP'S UNAVAILABILITY

It is essentially a temporal unavailability and a diminution in the factors that are accounted for in Total Productivity Maintenance (TPM) performance ratios[7]:



$$\frac{B}{A} = \text{Rate of time of operation} = \frac{\text{time needed - stopage time}}{\text{time needed}}$$

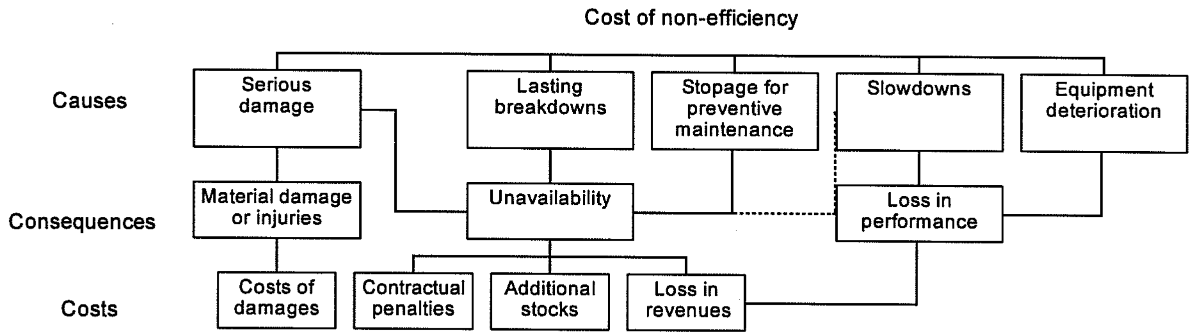
$$\frac{C}{B} = \text{Rate of duration of performence}$$

$$\frac{D}{C} = \text{Rate of productive performence}$$

$$\text{Global Performence} = \frac{D}{A} = \frac{B}{A} \times \frac{C}{B} \times \frac{D}{C}$$

Losses in performance and efficiency are detrimental to the cost control of an operation. Their causes could be attributed to serious equipment damage, non-critical lasting breakdowns, slowdowns, and stoppages for preventive maintenance. Unavailability does not constitute the only factor resulting in a loss of performance and efficiency. Equipment deterioration is also a factor. We will use the term 'costs of non-efficiency' to indicate the costs of loss in performance and loss due to equipment deterioration. The diagram[7] below illustrates the costs of non-efficiency.

[7] Boucly, Francis. Maintenance Management. AFNOR Tour Europe, 1990.



Using the above described Total Productivity Maintenance performance ratios, non-efficiency can be monitored and measured on a vessel with no maintenance management system in place versus one adherent to a management system. These TPM ratios could also be used to compare computerized maintenance managed environment versus a non-computerized one.

2.6 THE LONG RUN OPPORTUNITY COST OF SHIPS' TIME

It has long been recognized that the overall efficiency of ships in performing any given service is closely related to the time spent in that service. However, I found little evidence of attempts to quantify, in economic terms, the benefits of removing delays to ships, for example, by improving port turnaround time and its increasing costs, or by implementing technology, such as Computerized Maintenance Management Systems, to increase the ships' availability for service. Some evaluation of the cost of ships' time is also necessary in economic analyses of marine traffic congestion, routeing systems, navigational aids, and oil pollution reduction systems. Evaluating cost of ships' time could be used to evaluate predictable delays and time savings.

The implementation of a Computerized Maintenance Management System has a direct effect on time savings through reduced downtime and increased operational availability. In the next paragraphs we will derive the mathematical formulas for evaluating the cost of ship's time.

2.6.1 CAPITAL COSTS

To calculate the present value of a stream of costs and benefits, each year's value should be multiplied by a discount factor of value $(1 + r)^{-i}$. The Net Present Value (NPV)[8] is the result after the deduction of costs:

$$NPV = \sum_{i=0}^{i=n} A_i (1+r)^{-i} - C_o$$

r	rate of discount
i	the year of the vessel's life
A_i	net benefit in year i (cash revenue less cash operating costs in year i)
C_o	the initial capital cost
n	the life of the vessel

However, we are not concerned here with measuring the NPV over the life of a project, but with the measuring of the long-term opportunity cost by including capital charges equivalent to the capital cost. The annual capital charge can be calculated using the annuity formula[7] which converts the capital cost into a constant equivalent:

$$C_{cc} = \frac{C_o}{\frac{1-(1+r)^{-n}}{r}}$$

2.6.2 OPERATING COSTS

2.6.2.1 CREW WAGES

The labour costs per year are assumed to increase at an average rate approximately equal to the rate of growth of the economy in which they are resident. The present value (PV) of such a geometrically growing time series[8] is:

[8] Goss, R.O. Advances in Maritime Economics. Cambridge University Press, 1977.

$$PV = W_1 \left[\frac{1 - \left(\frac{1+g}{1+r} \right)^n}{r-g} \right]$$

Where g is the annual growth rate, and W_1 the initial value of the series. The present value can then be divided by the appropriate annuity factor to give the long term opportunity cost of labour costs spread over the entire life of the ship.

$$C_w = \frac{W_1 \left[\frac{1 - \left(\frac{1+g}{1+r} \right)^n}{r-g} \right]}{\frac{1-(1+r)^{-n}}{r}} = \frac{W_1 \left[r - r\left(\frac{1+g}{1+r} \right)^n \right]}{(r-g)\left(1-(1+r)^{-n}\right)}.$$

2.6.2.2 FUEL COSTS

They are taken as in port or at sea consumptions at relevant prices[9], representing the cost per day when the ship is idle or at sea.

$$C_{cf} = P_f H \left(2R_d F_p + \frac{mF_s}{24V} \right)$$

Where,

$$H = \frac{365 - S_d}{H_d} \quad \text{and} \quad H_d = \frac{m}{24V} + 2R_d$$

C_{cf} fuel costs per year
P_f the average price of fuel per ton
H round voyages per year
H_d days on each round voyages
F_p the daily fuel consumption in port in tons
F_s the daily fuel consumption at sea in tons
m round voyage in nautical miles
R_d days for turnaround at each port where cargo is worked

[9] Goss, R.O. Advances in Maritime Economics. Cambridge University Press, 1977.

S_d average days per year out of service for repairs and surveys
V ship's speed in knots

The expression for fuel consumption per year would become:

$$C_{cf} = P_f \left(\frac{365 - S_d}{\frac{m}{24V} + 2R_d} \right) \left(2R_d F_p + \frac{mF_s}{24V} \right)$$

2.6.2.3 REPAIR AND MAINTENANCE COSTS

Repairs and maintenance costs (C_{rmc}) cover all maintenance, upkeep, repair and replacement work except materials and labour supplied by the ship and already counted under "stores" or "crew wages". It is difficult to give a mathematical representation for these costs. They are usually available on an annual basis.

2.6.2.4 OTHER COSTS

They include insurance, stores, overhead, etc. (C_a). These costs are available on an annual basis

2.6.2.5 SUMMATION OF CAPITAL AND OPERATING COSTS

All above mentioned costs have been expressed on an annual basis. However, since ships spend some time each year under repair, the divisor for costs per day must be less than 365. After reviewing the literature, I noted that usually 350 is taken, not because these costs do not carry on during a repair period, but because we are calculating the opportunity cost of ships' time, which must be derived from the earning rate. If it is known that a ship will be under repair for an average of 15 days per year, this does not represent part of the opportunity cost of ships' time because it could not be earning revenue during this period. The greater the repair time, the greater the opportunity cost must be. Using the above formulas, we can calculate the long-run opportunity cost per day (C_{opp}).

$$C_{opp} = \frac{C_{cc} + C_{w} + C_{cf} + C_{rmc} + C_{a}}{350}$$

$$C_{opp} = \frac{\dfrac{C_o}{\dfrac{1-(1+r)^{-n}}{r}} + \dfrac{W_1\left[r - r\left(\dfrac{1+g}{1+r}\right)^{n}\right]}{(r-g)\left[1-(1+r)^{-n}\right]} + P_f\left(\dfrac{365 - S_d}{\dfrac{m}{24V} + 2R_d}\right)\left(2R_dF_p + \dfrac{mF_s}{24V}\right) + C_{rmc} + C_a}{350}$$

The need for determining a cost of ship's time is best illustrated by the pricing of chartered ships' rates. With chartered ships, like tankers, bulk carriers and tramps, the rates are either fixed for long periods by long-term charters or contracts and thus not subject to variation in respect of delays or, if arranged on the spot market, subject to much wider fluctuations, but never the less still subject to the opportunity cost of the ships' time.

CHAPTER 3: MAINTENANCE MANAGEMENT

Until recently, maintenance management was a manual activity placing large demands on company resources in terms of money, time, and human capital. The introduction of Personal Computers (PC) has resulted in the decentralization and computerization of the maintenance management function in several industries. In the marine industry, ships started to use Personal Computers and Local Area Networks for maintenance activities. Since the complexities of the maintenance tasks easily lend themselves to computerization, as well as the attractive savings in resources and environmental benefits that are obtained through an efficient preventive maintenance management program, a tremendous growth opportunity has been created.

3.1 LONG TERM OBJECTIVES OF MAINTENANCE MANAGEMENT

The ship owner or manager has two options to evaluate in his approach to the long term objective of maintaining his vessel. Like any piece of equipment, the ship is an ensemble of equipment, with a life cycle. The owner has the choice of setting a mid-range age at which he will sell the vessel or conserving it while continuing its maintenance with a direct cost of maintenance and an increasing non-efficiency cost. Identifying the optimal life time T* at which to obtain the optimal resale value of the vessel would help the owner in reaching his decision.

Suppose that a new vessel is bought at time $t = 0$. Acquisition cost is A, revenue at $t = 0$ is V_0, and total cost at $t = 0$ is C_0. RS is the resale value of the vessel.

The resale profit at periods $t = 0$ to $t = T\text{-}1$ are:

Period	Profit	
$t = 0$	$-A + V_0 - C_0$	
$t = 1$	$\frac{V_1 - C_1}{1 + r}$	(the net profit accrued between time zero and time $t = 1$)
$\vdots$	$\vdots$	
$t = T\text{-}2$	$\frac{V_{T-2} - C_{T-2}}{(1+r)^{T-2}}$	
$t = T\text{-}1$	$\frac{RS + V_{T-1} - C_{T-1}}{(1+r)^{T-1}}$	(profit made during the last period between $t = T\text{-}1$ and $t = T$)

The total profit is identified by the present value $\Psi(T)$ depending on the time T chosen for reselling the vessel.

$$PV = (-A + V_0 - C_0) + \frac{V_1 + C_1}{1 + r} + \ldots\ldots + \frac{V_{T-2} + C_{T-2}}{(1+r)^{T-2}} + \frac{RS + V_{T-1} + C_{T-1}}{(1+r)^{T-1}} = \Psi(T)$$

If the process described above is repeated every T years, the ship-owner obtains a stream of profits of $\Psi(T)$ every T years. The present value of this stream of profits is:

$$\Psi(T) + \frac{\Psi(T)}{(1+r)^T} + \frac{\Psi(T)}{(1+r)^{2T}} + \frac{\Psi(T)}{(1+r)^{3T}} + \ldots\ldots + \frac{\Psi(T)}{(1+r)^{(k-1)T}} + \frac{\Psi(T)}{(1+r)^{kT}} + \ldots\ldots = \Psi(T)\sum_{k=0}^{\infty} \frac{1}{(1+r)^{kT}}$$

$$= \Psi(T)\sum_{k=0}^{\infty} \left(\frac{1}{(1+r)^T}\right)^k$$

$$= \Psi(T)\sum_{k=0}^{\infty} a^k$$

where $$a = \frac{1}{(1+r)^T}$$

Let $x = \sum_{k=o}^{\infty} a^k$,

then:

$$
\begin{aligned}
x &= 1 + a + a^2 + a^3 + a^4 + \dots\dots\dots \\
&= 1 + a(1 + a + a^2 + a^3 + a^4 + \dots\dots\dots) \\
&= 1 + ax \\
&\Rightarrow x(1 - a) = 1 \\
&\Rightarrow x = \frac{1}{1-a}
\end{aligned}
$$

and $x = \sum_{k=o}^{\infty} a^k = \frac{1}{1-a}$

The present value of the stream of profits would be:

$$
\begin{aligned}
\Psi(T)\sum_{k=o}^{\infty} a^k &= \Psi(T)\frac{1}{1-a} \\
&= \Psi(T)\frac{1}{1 - \frac{1}{(1+r)^T}}
\end{aligned}
$$

The optimal life time of a vessel is the value of T that maximizes:

$$
H(T) = \Psi(T)\frac{1}{1 - \frac{1}{(1+r)^T}}
$$

The first order condition would be: $H'(T^*) = 0$

The solution of this equation gives the life time (T*) of the vessel at its optimal resale value.

3.2 RELIABILITY

The reliability and maintainability of equipment depend essentially on the quality of the design.

The reliability of the critical elements of equipment and machinery has to be known in order to optimize the maintenance process. They can be expressed qualitatively with respect to the nature of failure possibilities, such as progressive or sudden failures, or deterioration due to usage with increasing failure rate as time progresses, or redundant failures of constant rate of occurrence[10]. A complete knowledge of the reliability characteristics of these critical elements would necessitate determining the corresponding quantitative parameters, such as:

- the function of reliability R(t) which is the probability of proper operation or survival of the element at a time t
- the probability of failure at time t: $F(t) = 1 - R(t)$

and the probability density function of failure at time t, which is the derivative of F(t) with respect to time

$$f(t) = \frac{dF(t)}{dt}$$

the rate of failure at time t:

$$\lambda(t) = \frac{f(t)}{R(t)} = -\frac{R'(t)}{R(t)}$$

From that last expression, knowing the rate of failure would allow us to determine the rule of reliability R(t) using:

$$R(t) = \exp\left[-\int_0^T \lambda(t)dt\right]$$

In the special case where the failure rate is constant in time, $\lambda(t) = \lambda$, and $R(t) = e^{-\lambda t}$.

The Mean Time Between Failure (MTBF) would then be:

$$m = \int_0^\infty e^{-\lambda t}dt = \frac{1}{\lambda}$$

Here, again, computerized maintenance systems are found to be quite useful in compiling failure and reliability information and computing the MTBF for the different equipment on board ship.

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[10] Boucly, Francis. Maintenance Management. AFNOR Tour Europe, 1990.

3.3 PREVENTIVE, CONDITIONAL, CORRECTIVE AVERAGE COSTS AND FAILURE RATES

Preventive, conditional, and corrective maintenances are the three predominant types of maintenance. Preventive maintenance is a systematic approach to maintaining the equipment based on manufacturers' recommendations and secure methods for minimum failures. Maintenance actions are often undertaken even if not needed. Conditional maintenance is based on the new maintenance principle of: "if it is not broken, why fix it". That principle is coupled with frequent periodic condition monitoring programs where unnecessary maintenance actions are eliminated. Corrective maintenance is based on the principle of maintaining the equipment only when it fails. It is identified as the maintenance program with the highest long-term cost.

The economic criteria for choosing between the three types of maintenances consist of minimizing the average total cost of maintenance and the unavailability per unit of service time.

Let us define the following terms:

p	the cost of a preventive intervention conducted in favorable conditions
P	additional cost incurred as result of a failure
F(T)	probability of failure at the end of a duration T of the service rendered by the concerned critical element. A corrective intervention is necessary in the F(T) proportion. It is the corrective, accidental, or residual proportion of the systematic preventive maintenance
g	the cost of conducting a conditional maintenance
K	a derived factor very close to unity (1)
m(T)	average duration of the concerned element in the case of a systematic preventive replacement or overhaul after a duration T, where:

$$m(t) = \int_0^T (1 - F(t))dt$$

The average total costs and corresponding failure rates for the three types of maintenances are[11]:

Type of Maintenance	Total Average Cost	Failure Rate
Preventive (Systematic)	$c_1 = \frac{p + PF(T)}{m(T)} + \text{minimum}$	F(T) generally different from 0
Conditional	$c_2 = \frac{p + g}{K \times (MTBF)}$	0%
Corrective	$c_3 = \frac{p + P}{MTBF}$	very high

At this stage of the paper, it is imperative to note that up to this chapter inclusively we have developed the equations necessary for a mathematical evaluation of the benefits of Computerized Maintenance Management in the marine industry. However, in the next chapters, the analysis of the benefits will not be demonstrated using the developed equations due to the scope of such an undertaking which is beyond the purpose of this paper. Therefore, instead, we will proceed through a detailed discussion of all related issues and demonstrate the benefits resulting from implementing Computerized Maintenance Management Systems.

[11] Boucly, Francis, Maintenance Management. AFNOR Tour Europe, 1990.

CHAPTER 4: WHY COMPUTERIZE MAINTENANCE MANAGEMENT?

It has become commonly accepted that maintenance represents a significant portion of the cost of doing business or providing a service. The portion of cost that maintenance represents will continue to increase as the various forms of automation increase. It therefore behooves us to make optimum use of that resource called maintenance.

Planning and scheduling of maintenance is one of the ways of optimizing the use of this resource. Normally, however, one of the problems is the amount of clerical work, or "paper shuffling," associated with such planning and scheduling. Computerization, if properly conceived, can minimize this problem.

Computerization can provide backlog information for various types of work; availability of materials; costs by job, facility, or type of work, etc., easily. It can increase effectiveness of planning, scheduling, and cost tracking by as much as 50 percent[12]. In addition, it can frequently provide types of information not normally available, at no additional cost.

4.1 COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEMS

Computerized Maintenance Management Systems receive a disproportionate amount of attention by management. This is because many companies believe computers are the panacea to all the problems facing modern maintenance departments. This perception began just after the 1982 recession, when maintenance departments were still reeling from the effects of extensive cost-cutting programs. In most cases, budget cuts included staff reductions, especially maintenance

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[12] Higgins, Lindley R. Maintenance Engineering Handbook. 4th edition, McGraw-Hill Book Company, 1988, p. 3-16

planners and clerical support for maintenance management systems. Even maintenance departments boasting good manual systems had to carry the burden of increased clerical responsibility shared among fewer people. This was the death of many maintenance management systems in many marine and land based companies.

When the cloud lifted in the mid-1980's[13], companies saw the computer as a means of saving the annual salary expense associated with hiring back clerical support personnel lost in the recession. Firms rushed into computerization without proper planning for such a major change and systems were purchased which did not satisfy the specific needs of the users, and were too rigid to mold to the company's specification rather than the reverse.

Users were in many cases not involved in the initial decision-making process. Sometimes, Information Systems departments would make the decision almost entirely on their own. Also, a critical mistake made by some companies was selecting a vendor who could not provide adequate support.

In many cases, these problems still persist today. However, most companies that do make the investment in computerized maintenance management systems reap some benefits. The greatest savings stem from improved productivity of the maintenance department and the reduction of downtime. This, in turn, comes from better planning and scheduling for preventive maintenance and regular work orders, as well as quicker response time. A comprehensive equipment history allows good management decisions respecting equipment replacement and labour utilization.

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[13] Higgins, Lindley R. Maintenance Engineering Handbook. 4th edition, McGraw-Hill Book Company, 1988

There can be significant material savings as well through reduced maintenance inventory levels, better purchasing, and improved material planning and control. Since microcomputer-based maintenance management systems were introduced, hundreds of vendors have appeared offering a wide range of packaged software with widely varying features and options.

As is true with other software applications, high price does not necessarily coincide with high functionality. Many mainframe packages have not kept pace with microcomputer software because of the excessive development costs born by the mainframe environment. As well, the market for microcomputers has enjoyed rapid growth as the gap narrows between the speed and performance of micros, mainframes, and many low-end systems have more features and functions than large mainframe packages.

Another breakthrough for the Computerized Maintenance Management System industry was the move to more open systems. This revolution is still underway, allowing users to more easily integrate third party software such as CAD, project management, accounting, predictive maintenance, report writers and graphics generatives.

There are four components of computerized maintenance management systems. Preventive maintenance (PM) is currently in the limelight; it is also referred to as Planned Maintenance. Many top management groups have identified preventive maintenance as being of strategic significance. Inventory and spare parts control ranks second in popularity, as companies continue to adopt inventory reduction programs. Work order control provides the means to plan, schedule and control labour and material. Equipment history then summarizes the labour, material, and downtime costs associated with maintaining a given piece of equipment.

4.2 TECHNOLOGICAL AND COMPETITIVE ENVIRONMENTS

The Marine Shipboard Technology sector is a high-tech industry. Areas of recognized capabilities include hydrographic and oceanographic instrumentation, subsea robotics and remotely operated vehicles, remote-sensing systems, navigation and communication systems and "smart ship" technology covering maintenance and inventory software packages.

Computer software represents a crucial element in industrial development. Computer hardware is becoming increasingly sophisticated, but its real cost continues to decline. As a result, hardware is now simply a commodity; software is where the research action and the financial returns are.

Large economies of scale are achieved in the horizontal applications software where a package has application in different industry sectors. Generic applications to diverse industries determine that those participate in an industry with low barriers to enter. With such high and growing demand for software and such low barriers to entry into the software industry, it is not surprising that the sector is enjoying solid growth.

The major competition in the marine industry comes from the US, Norway and the United Kingdom. The software and service sector, particularly the software-products business, is highly competitive and risky. Competition in the software industry is at an all-time high. Product prices are falling, new technologies are being introduced and sales and marketing techniques are becoming more sophisticated.

ATTRACTIVENESS OF THE INDUSTRY ENVIRONMENT
MAINTENANCE MANAGEMENT SOFTWARE

	HIGH	LOW
THREAT OF ENTRY		
Economies of scale are high		X
Product differentiation/brand identification is high		X
Capital requirements are low	X	
New participants face major cost disadvantages relative to old participants		X
Distribution channels are not locked up	X	
Government policy does not limit entry	X	
Current firms possess substantial resources	X	
Industry growth is high	X	
SUPPLIER POWER		
Industry is less concentrated than the suppliers	X	
Product is differentiated	X	
Switching costs are low for firms in the industry		X
Substitute supply products exist		X
Industry is an important one for the supplier		X
BUYER POWER		
Few buyers purchase in large volumes	X	
Products are differentiated		X
Switching costs for buyers are low	X	
Product cost is not a significant portion of buyers' total cost	X	
Product/service is very important to the buyer		X
There are few alternative firms		X
Product/service saves the buyer a lot of money		X
INDUSTRY RIVALRY		
There are many competitors	X	
Industry growth is high	X	
Switching costs between competitors are low	X	
Exit barriers are low		X
The product is relatively unimportant to firms		X
Rate of change is low		X
THREAT FROM SUBSTITUTES PRODUCTS		
An alternative product/service is available	X	
Price of substitute is low	X	
Switching costs are low	X	

4.3 IMPLEMENTATION COSTS

A person's first impression would be that implementation costs of a Computerized Maintenance Management System are very high due to high equipment cost, high software cost, start up and transition difficulties, and high training and installation costs. That person's impression would lead to believe that complications associated with a change from a manual maintenance management system to a computerized management are somewhat more costly then the potential benefits resulting from the implementation of Computerized Maintenance Management Systems. Fortunately, that person's impression is somewhat inaccurate. Field experience and observations show that most difficulties are minor. A properly designed system and transition phases including training, installation and data lift-up should lead to smooth and problem-free transition from a manual maintenance management system to a computerized maintenance management system.

The table below shows typical costs[14] involved with the implementation of a computerized system on one medium size vessel (50,000 DWT).

		System Estimated Cost[14], ($US)
Software license		$ 10,000
3 Computer Stations & Security Back-up Equipment		$ 8,000
Data Lift-up and System's Installation		$ 50,000
Training		$ 10,000
License Maintenance & Future System Upgrade	15% of license fee	$ 1,500
Satellite Ship to Shore Link (optional)		$ 20,000
Estimated Total		**$99,500.00**

[14] German & Milne Ltd., Ottawa, Ontario. A Marine Maintenance & Naval Architect Co.

CHAPTER 5: BENEFITS

5.1 BENEFITS OF COMPUTERIZATION

With increased availability and affordability of computer resources, the benefits of computerization are becoming accessible to more areas of marine fleet management. Although the functions performed and the advantages promised vary, in general, the benefits of computer automated maintenance can be classified into four basic types: reduced costs, greater access to information, better planning, and increased control.

5.1.1 REDUCED COSTS

The oldest and most frequently cited benefit of computerization is lower cost, either because the same work can be done with less effort, or because more work can be done with the same effort. Either way, the computer cuts the cost per unit of work accomplished. Manually intensive functions requiring repetitive clerical tasks are obvious opportunities for this type of computer solution. Work orders are streamlined with an automated work order issuing and reporting mechanism.

Computerization also beneficially affects maintenance work itself using the computer as a job-planning tool improves the efficiency of the planner, reduces errors, and can even streamline the maintenance work itself. Standard job plans can be stored on computer and easily modified for the specific circumstances of the job. The computer cuts the planner's time and, because the standard plan has all the parts and tools identified for successfully performing the maintenance job, ensures that the job is done right and with a minimum of backtracking to get forgotten items. The computer is also used to determine the most cost-effective preventive maintenance interval, to efficiently manage inventories of parts and stores and to reduce the expense of training new personnel.

5.1.2 GREATER ACCESS TO INFORMATION

Often, useful — perhaps even invaluable — information is either unavailable or very cumbersome and time-consuming to obtain. The computer can help make information readily accessible by storing data in retrievable form and by facilitating data manipulation and reporting. Information can be obtained on a regular basis in the form of periodic reports, but it can also be accessed or provided on an ad hoc basis from a computer screen.

5.1.3 BETTER PLANNING

Greater access to information, coupled with the speed and flexibility of the computer, enables maintenance management to do a better job of planning and coordinating their efforts. Regular planning tasks, such as budgets and manpower plans, as well as non-recurring plans, such as preventive maintenance interval determination and inventory reordering point analysis, can be streamlined and improved significantly. Plans are quickly constructed. Changes are easily accommodated. More versions can be tested and evaluated before a final approach is accepted. The computer is also a powerful tool for simulating a proposed plan so that unanticipated flaws can be ironed out prior to implementation.

5.1.4 INCREASED CONTROL

The combination of these benefits leads to a further benefit of computerization: increased control over maintenance operations. Streamlining manual, clerical tasks; accessing information previously impossible to obtain quickly and easily; and better operations planning result in improved management control of day-to-day functions. With these resources, the engineering superintendent or maintenance engineer is better informed and better able to take action before problems arise, rather than waiting passively for the next crisis.

5.2 SAVINGS

Savings come from decreased equipment downtime, increased staff utilization and increased utilization of other resources such as shop equipment, parts and tools. Listed below are savings and benefits specific to each of the four CMMS modules mentioned previously.

5.2.1 WORK ORDER CONTROL

A proper work order control system can yield the following savings and benefits:

- Work is prioritized and monitored so higher priority jobs are acted upon first.
- Maintenance staff are given more timely and more accurate descriptions of work, crew breakdown, etc., therefore assessing the problem and solving it are easier.
- Maintenance staff must complete work within a reasonable, predetermined standard; a variance from standard must be explained.
- Through a work order status report, a maintenance planner can identify problem work orders, investigate the job and take corrective action.
- Maintenance planners can set targets for reducing equipment downtime for every cost centre.
- Proper crew type and size can be assigned.
- Idle time and overtime are minimized since an optimum schedule is developed through use of backlog report, maintenance report, standards, priority, etc.
- Excessive paperwork is reduced using standing work orders.

- Better scheduling leads to better allocation of other resources (shop equipment, parts, tools).
- Variance from planned number of labour hours can result from waiting for tools, parts, or shop equipment; corrective action can be taken.

5.2.2 PREVENTIVE MAINTENANCE

The following savings and benefits must outweigh the cost of implementing a PM system:

- Greater safety for workers and improved protection for the engine room and other facilities on board, lead to lower compensation and insurance costs.
- Less downtime offers related savings and operational benefits.
- Repair costs are lower for simple repairs made before breakdowns.
- Less overtime is paid on ordinary adjustments and repairs than for breakdown repairs.
- There is greater yield; reduced waste, scrap, and giveaway; fewer rejects and returns; and less damage because of properly adjusted equipment.
- Equipment reliability and availability are greater.

5.2.3 INVENTORY CONTROL

A proper inventory control system provides savings in three key areas - reduced inventory levels, increased inventory turns, and reduced stock-outs. The following are additional savings and benefits:

- Simplification of the reordering process for stock items.
- Provision of usage history to assist purchasing in assessing suppliers, requesting quotations, etc.
- Reduction of costly rush orders.
- Collection of historical data to assess supplier service records.

- Establishment of a costed book inventory system.
- Increased tool availability through better control of receipts and issuances of tools.
- Improvement in response time to breakdowns.
- Reduction of pilferage and waste.
- Identification of obsolete inventory items for faster disposal and reduction of inventory space requirements.

5.2.4 EQUIPMENT HISTORY FILE

The equipment history file provides the following benefits:

- Filing the completed work orders would effectively provide back-up to a computer system.
- Since data on the various components are together in one file, potential users have an easily accessible source of information.
- The equipment history file highlights problem areas, and promotes effective solutions by revealing the true sources of the problems.
- Downtime information is used in the assessment of the maintenance department performance and in the cost justification of equipment replacement.
- Labour and material cost data tracked via work orders and time cards would provide a valuable information base for economic analyses for the replacement of equipment.

5.3 SOURCES OF SAVINGS

Cost-justifying a Computerized Maintenance Management System program is no easy task. There are several sources of potential savings such as maintenance labour (increased utilization, improved performance, reduced overtime, and less turnover), maintenance material (decreased storage and material handling, reduced stock-outs, and few rush orders), capital equipment (reduced downtime, increased reliability, and improved equipment performance), and energy. Each of these areas is detailed below.

5.3.1 MAINTENANCE LABOUR

5.3.1.1 INCREASED UTILIZATION

Using work sampling, suppose it is determined that the average utilization of a fleet of 10 vessels of 50 maintenance engineers is 60 percent (in most maintenance organizations it is approximately 50 percent). This means that 50 person-years are required to perform 30 person-years of work.

Idle time can be caused by excessive queuing for parts, waiting for further instructions, waiting for a machine to become available and simply waiting for another breakdown. If a 10 percent increase in utilization were achieved, then five person-years would be freed for work on special projects, more emphasis on preventive/predictive maintenance, or if necessary, a layoff of five people saving approximately 5 x $50,000 - $250,000 annually. A 10 percent improvement in utilization would come from better planning and scheduling, more emphasis on planned maintenance which is easier to schedule more tightly, and methods' improvement.

5.3.1.2 IMPROVED PERFORMANCE

Even if utilization is high, it is imperative to maximize performance, namely the speed, effort and skill exercised in properly completing a task. Through work measurement, suppose it is determined that the average worker performance is 80 percent of standard.

Continuing the example above, with 50 maintenance workers and an estimated six percent improvement in performance, an additional three person-years would be available equivalent to $150,000 in savings.

5.3.1.3 REDUCED OVERTIME

One of the most difficult problems to overcome is chronic overtime. Through better planning and scheduling in conjunction with operations, as well as improved matching of work backlog to manpower requirements across all shifts, assume a 10 percent reduction in overtime is achievable. If overtime costs $750,000, then expected annual savings would be $75,000.

5.3.1.4 LESS TURNOVER

More satisfied workers also means less turnover of personnel. Turnover can be costly in terms of extra recruitment and training costs, and loss of productivity due to learning curve effects and disruption to fellow workers. If turnover is 12 percent, and it costs $5000 to hire and train new employees, then $5,000 would be saved for every two percent reduction in turnover (i.e., 0.02 x 50 maintenance workers x $5000). A 10% reduction in turnover would result in annual savings of $25,000.

5.3.2 MAINTENANCE MATERIAL

The main benefit of doing away with the need to carry additional spares on ships would be the savings realized from not having tied up capital. With an average inventory holding of about $800,000, a company operating about ten ships stands to realize a saving in blocked capital of $8,000,000. Initially there would be an additional cost for new computer software and more frequent spares supplied to the vessel. While initial costs will be high, the long term benefits would offset this cost easily. The main criterion in successfully implementing the system would be to find a single, or limited few suppliers capable of and willing to work together with the ship-owner on a long term basis. Owners or ship managers main criterion in selecting a supplier, places price as the top priority, followed by other factors such as location, dependability, etc. With the system of doing away with large on board inventory, dependability and reliability of supply would have to be the main criterion for selection of a supplier, followed by location.

5.3.2.1 DECREASED STORAGE AND MATERIAL HANDLING

There are direct savings from reduced inventory levels and material purchases. These might be as a result of better control systems, greater planning of purchases, more effective troubleshooting and repair techniques, and so on. Reduced inventory level and material purchases can, in turn, result in further savings from reduced storage and material handling requirements. Savings must be expressed as an opportunity to use the space/equipment for other purposes, or avoid the cost of adding space or buying new equipment.

5.3.2.2 REDUCED STOCK-OUTS

Further savings will result from a reduction in stock-outs. The right combination of re-order point, order quantity and resultant service level can be calculated for critical parts using a good computerized inventory control system. You cannot simply reduce the frequency of stock-outs to zero, as this would cause inventory levels to sky-rocket. Fewer stock-outs contribute to reduced equipment downtime and improved staff utilization.

5.3.2.3 FEWER RUSH ORDERS

Improved inventory planning and control, and greater emphasis on planned maintenance can result in virtually the elimination of rush orders. Rush orders can be very costly if parts are purchased without getting quotes, at odd hours, and using expensive means of transport. Savings can be estimated using historical records.

5.3.3 CAPITAL EQUIPMENT

5.3.3.1 REDUCED DOWNTIME

One of the most significant savings in implementing a Computerized Maintenance Management System program is the reduction of equipment downtime. Savings stem from greater planning and tighter control systems, closer attention to equipment history trends, and quicker response to breakdowns. These measures will decrease the severity of breakdowns and increase the mean time between failures (MTBF). If the total investment in equipment is $20 million, then an average one percent reduction in downtime means approximately $200,000 worth of equipment is "made available." The actual dollar savings will depend on the number of pieces and type of equipment. You cannot save a fraction of a machine with a small, less expensive one.

Some companies express downtime savings in terms of a spares ratio. Suppose there are 20 identical pieces of equipment each costing $50,000. At any given time there are two pieces of equipment experiencing downtime suggesting an average spares ratio of 2:20 or 10 percent. If downtime were reduced such that, on average, only one piece of equipment was out of commission, then one piece of equipment costing $50,000 could be saved when replacing one of the 20. Alternatively the extra machine could be sold, used for training, used for spare parts, or used to increase capacity.

5.3.3.2 INCREASED RELIABILITY

Equipment will last longer if the actions described above are implemented (i.e., improved planning). Thus, a $20 million capital investment would be replaced say, three months later, yielding savings of $0.5 million. This assumes the $20 million, which would have been used to replace the equipment, could instead be invested for the three months at 10 percent annual interest. However, additional maintenance expenses would be incurred in order to extend the life of the equipment. These expenses must be estimated based on average maintenance costs and netted against the $0.5 million.

5.3.3.3 IMPROVED EQUIPMENT PERFORMANCE

Again, through similar actions as described above, equipment can be run closer to the factory-stated peak performance. Suppose a machine is designed to run with an output of 100 percent, however, actual performance has historically been 80 percent efficiency (ignoring downtime). Therefore, a five percent increase in performance results in a rate of output of 84 percent. Savings are roughly equivalent to a five percent decrease in downtime.

5.4 COMPILATION OF SAVINGS

This section gives a tabulated compilation of benefits and savings that would result from the implementation of a Computerized Maintenance Management System on a fleet on 10 vessels. We will assume that the composition of the fleet is ten 50,000-DWT (dead weight tonnes) vessel.

The average total operating cost for such a vessel per year is approximately US $12 million .

Below is a tabulation of the cost affected by the implementation of a Computerized Maintenance Management System.

	Minimum Percent of Total Operating Cost	**Equivalent Amount per Vessel ($US)**	**Amount for the Fleet of 10 vessels ($US)**
Crew Costs	15%	$1,800,000	$18,000,000
Fuel Costs	12%	$1,440,000	$14,400,000
Repair & Maintenance Costs	10%	$1,200,000	$12,000,000
Insurance Costs	6%	$ 720,000	$ 7,200,000

In the following table, are presented potential savings resulting from the implementation of CMMS.

Category	Source of Savings	Result or ±%	Savings for the fleet of 10 vessels (USD)
Labour	Utilization	+ 10%	$ 250,000
	Performance	+ 6%	$ 150,000
	Downtime	- 10%	$ 75,000
	Turnover	- 10%	$ 25,000
Material	Eliminate Inventory Holding - $800K/ship		$8,000,000
	Reduce Storage & Handling Requirements	Increase Equipment Availability	
	Reduced Stock-Outs	Reduced Downtime Increased Staff Utilization	
	Reduced Rush Orders	Lower Cost on Parts	
Capital Equipment	Reduced Downtime by 50% from 4:40 spare ratio to 2:20	$200,000 per Vessel in Equipment Made Available	$2,000,000
	Increase Reliability by Extending Equipment Life-Cycle by 3 months	3 Months Interest on Capital Allocated for Equipment Replacement	$ 500,000
	Equipment Performance	- 5% Downtime	
SAVINGS PER FLEET			**$11,000,000**
COST OF CMMS (including installation)		$100,000 per vessel	**$ 1,000,000**
TOTAL NET SAVINGS			**$10,000,000**

CONCLUSION

The International Organization for Standardization (ISO) is a worldwide federation of national standards-writing bodies, representing over 90 countries including Canada, the United States, the European Community and Japan. The ISO 9000 series of standards is an internationally accepted system of rating quality management and quality assurance. Developed in 1987, it provides the elements for a quality system, regardless of industry or economic sector. Implementation requires adapting the ISO quality philosophy to a company's objectives, products, processes and practices. ISO certification affiliation is optional. Certain governments have made it a requirement for its suppliers and service providers especially when concerning military related products and services. The Canadian Department of National Defense has indicated in the spring of 1995 the intention to request from its suppliers an ISO 9000 compliance starting 1996 and certification affiliation starting 1997. Over 50 countries have already adopted ISO 9000. More and more companies are seeking ISO 9000 certification as it becomes an imperative of competitive advantage.

In 1994, the International Maritime Organization (IMO), a United Nations agency, presented a new challenge to the maritime industry by setting the new International Safety Management (ISM) Code[15], which will come into force July 1, 1998. The ISM Code requires that all special and critical operations onboard vessels be documented to increase safety and prevent pollution. This includes operations such as maintenance, cargo handling, navigational and many others. This ISM requirement renders ISO compliance (not certification) a strict minimum for shipping companies. For many ship managers and owners, the most time consuming part of qualifying for

[15] International Maritime Organization Annual Report, United Nations, 1994

the ISM Certificate, is the implementation of the planned maintenance management system. This system is based on documentation on all important mechanical and electrical equipment onboard, inventory of spare parts, and rules and recommendations for maintaining all essential machinery and equipment according to classification societies' rules. The need for computerized shipboard maintenance management system to handle documentation and reporting requirements became clear.

To implement all the necessary changes inherent in the ISM certification process including the maintenance management system, a typical time-frame would be two years. Ship-owners and ship mangers will, by the 1st of July 1998, need an ISM Certificate of Conformity. If they do not manage to obtain one, the consequences could be costly. The international community wants to rid itself of environmental unsafe ships and the shipping industry agrees.

If ship-owners and ship managers choose to neglect the ISM Certificate, the consequences are costly but simple. Charterers will be reluctant to offer any cargoes. Insurance companies will either decline to insure their fleets or demand exorbitant premiums. Many flag states will not allow the ships to enter their waters.

Compliance with the ISM Code can result in lower running costs, fewer pollution spills, better trained and motivated crews, officers and management organizations, and reduced insurance premiums. Acquiring the ISM certificate will undoubtedly change the way ship-owners and managers will operate their ships and their companies. It entails clear-cut new policies, new lines of responsibility, communication and authority both ashore and onboard, relocation of resources, tailor-made training schemes, large quantities of documentation and new computer software.

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