A CROSS SECTIONAL ANALYSIS OF SHIP MAINTENANCE EXPENSES

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Abstract

This cross sectional study introduces an econometric model to explain the determinants of expenditure in ship maintenance. The data was collected from ten Greek owned Shipping/ Managing companies for the year 1999 and consists of 112 vessels of different types. On the methodological plain the best functional form is obtained when using a log linear model. As expected from theory, the empirical results show that maintenance expenditure is positively related to age, size and utilization. In addition, the effect of age is found to be stronger on vessels younger than 20 years, while the effect of utilization is weaker for them. This may be due to the fact that vessels less than 20 years old can be sold more easily in the second hand market, whereas older vessels have a shorter lifetime and are also constrained by safety regulations. Therefore, shipowners are more reluctant to spend more once the vessel passes its 4th and especially its 5th special survey. In the estimated model, the inclusion of company dummies was necessary to achieve a better fit. It was found that company presence is most noticeable when stores expenses were estimated separately. Therefore, company policy has still some control on maintenance expenses. Another important result is that the elasticities of maintenance expenses with respect to age, size and utilization were uniformly less than one during 1999.

Keywords: Shipping; Stock replacement
Topic Area: A2 Maritime Transport and Ports

1. Introduction

Shipping Owning and Management companies (henceforth SOMs) are facing new pressures and challenges in procuring an effective and cost efficient maintenance schedule. During the 90's, a new stream of regulations and the increasing activity of State Port Authorities in ensuring that visiting vessels satisfy their seaworthiness certificates changed the perception on how ship maintenance should be dealt. Indeed, the new policy trend towards eliminating substandard ships aims at improving seaworthiness and at raising the quality and quantity as well as the frequency of maintenance. Overhauling, in terms of major surveys, is no longer perceived to be the only means of maintenance but rather regular maintenance is required to be preventive in nature and allow for upgrading the equipment and condition of the vessel. Thus, understanding which factors contribute in what way and by how much towards maintenance effectiveness may assist managers optimise the allocation of respective resources in their efforts to determine the useful lives of their vessels, and thus, to an extent, their policies regarding fleet composition and replacement.

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The literature to which we could turn for helpful leads in our research focuses mainly on the theory of replacement and much less on utilisation, maintenance and the other decisions pertaining to ships in particular and to equipment in general. Jin and Kite-Powel (1999) studied the issue of fleet renewal and found that ship replacement and ship operating decisions are taken jointly so as to permit maximum fleet utilisation. But they did not pay attention to maintenance. A decade earlier Evans (1989) analysed the problem of ship replacement under technological obsolescence and ship modifications, but without considering the issues that are associated with ship utilisation and maintenance. At about the same time Ye (1990) investigated equipment replacement with emphasis on the stochastic nature of maintenance and operating costs, but without allowing for *upgrading*, *downgrading*, *overhauling*, *stripping*, *idling* and disposing of equipment. In short, by concentrating on a few of the relevant decisions and ignoring the rest, all specialised and general purpose literature has adopted a partial equilibrium approach to study a problem, which is essentially general equilibrium in nature. For this reason the model that came closer to serving our research objectives is the one that has evolved from the contributions by Bitros (1976a, 1976b, 1999, 2000) and more recently by Bitros and Flytzanis (2002a,b).

At its current stage of development this model is characterised by several main advantages. One of them is that it encompasses all significant operating and equipment policies. In particular, with respect to the former the model determines the various facets of *utilisation* and *maintenance*, whereas with respect to the latter the model determines *service life*, *expansionary investment, overhauling investment* and *stripping disinvestment*. Another advantage is that all these policies are derived from a unified analytical framework based on rational economic behaviour. So each policy is decided consistently with the others and with the objective(s) pursued by the owner of equipment. And still another advantage is that the model can be extended to allow for product and input market considerations, specific features relating to the type of equipment in question, etc. Therefore, while we adopt this model as a backbone for our estimations, we test also for additional factors that may potentially affect shipping maintenance outlays.

Our data come from the records of 112 vessels during the year 1999. Following the classifications used in the Profit and Loss (P&L) accounts of their SOMs, total maintenance expenses are distinguished into the categories shown in Table 1. On the other hand, since maintenance expenses may vary significantly by type of vessel and flag of registration, Table 2 exhibits the distribution of sample ships along these factors. Moreover, a similar break down by age reveals that the sample is composed of vessels mainly in the10-20 year brackets and to a lesser extent of younger and older ships. Thus to our view the data are quite sufficient to support the intended tests for at least three reasons. First, because they enable us to distinguish among upgrading, regular and periodic maintenance by fitting the model respectively to expenses for stores, spares and repairs during surveys. Second, because in addition to other factors we can control for the influence of such fundamental characteristics as the type of vessel and its age and flag of registration. And, thirdly, because of its stratification by reference to standard criteria, the sample was quite representative of the world fleet in 1999.

On the theoretical plain, the estimated model took a log-linear form and fitted well the observations. Irrespective of ship type segmentation three key factors seems to explain total ship maintenance expenses; these were the age, the size and the utilisation of ships. In addition we estimated the effect on maintenance for vessels under 20 years old and for each type of vessel in the sample. The results confirm Frankel's (1991) findings that total maintenance expenses increase for vessel over 20 years, though this increase is not as dramatic as it is presumed. Last, but not least, we estimated separate models for stores, spares and repairs/surveys and found that the issue of upgrading is still a company policy matter.

Table 1: Break down of total maintenance expenses according to the P&L accounts of SOMs

Stores	**Spares**	**Repairs/Special surveys**
• Deck stores	• Paints	
• Engine stores	• Safety equipment	
• Engine chemicals	• Slopes	
• Forwarding expenses for stores	• Spare parts for repairs	

Table 2: Distribution of ships by type and registration flag

Types of ships[1]	Flag of registration					
	Bahamas	**Cyprus**	**Greek**	**Malta**	**Panama**	**Total**
BC < 45,000dwt[2]						**32**
BC < 80,000dwt						**22**
BC <175,000dwt						**9**
GC						**15**
LPG						**28**
Tanker						**6**
Total	**14**	**4**	**47**	**14**	**33**	**112**

Notes:
1. The initials in this column have the following meanings: BC=Bulk Carrier, GC=General Cargo, LPG=Liquified Propane Gas.
2. Dead Weight Tons (DWT).

On the practical side, the results may have quite useful implications. With regard to maintenance decision-making it is found that the yard where major repairs take place is of importance. Given our sample, we point out a number of yards that raise total ship maintenance expenditure. When separate models for stores, spares and repairs expenses are estimated, it turns out that ships, which are not painted with epoxy coating on cargo and ballast tanks at construction, exhibit increased spares maintenance expenses. Vessels that are built with high tensile steel result also in higher repair expenses because of the need to replace the old thin steel with new one. Interestingly, in the estimated model for stores the effect of company dummy is the most apparent one than anywhere else. Hence it is here where most likely company policy could have more control on maintenance expenses given the new regulations, even though it may be the case that it could reduce the quality and standard of maintenance.

The rest of the paper is structured as follows. The next section lays down the formulation of the general equipment model and the considerations that were introduced to adapt it to the characteristics and operating conditions of ships. Section 3 describes the sources of the data, the definitions of the variables that enter into the various specifications of the model. Section 4 presents the estimated models and interprets the significance of the results from both the theoretical and the practical point of view. Section 5, concludes the paper and offers suggestions for further research.

2. The model

Having defined Ship Maintenance Cost and before suggesting which factors may affect maintenance expenses, it is important to introduce a general theoretical model. The use of a model can help understand how factors are included in the maintenance cost function and in addition, direct further studies in examining all factors, which may require time series data. In order to build a model we use a theoretical replacement model introduced by Naslund (1966), that has been applied in other studies such as those concerned with railways and cars. For example under this framework Bitros (1996) undertook a cross sectional study on the automobile industry with a few minor changes.

The issue of solving a problem of optimal replacement by maximising utilisation, maintenance work and the life time of an equipment provides the starting point to create the basic econometric model, which is used in this study. The following model can explain in a world without uncertainty how a shipping firm plans its repair policy and the service life of its fleet:

$$\underset{\{u(t),\, m(t),\, T\}}{\text{Max}} \qquad B = \int_0^T [g(u(t) - w(m(t))]e^{-rt}dt + S(T)e^{-rT} \qquad (1)$$

$$\dot{S}(t) = f(t)m(t) - \delta(u(t)) - \xi(t) \qquad (2)$$

$$S(T) - C_d \geq 0,\ C_d \qquad (3)$$

$$0 \leq m(t) \leq W, W > 0 \qquad (4)$$

$$u(t) \geq 0, m(t) \geq 0, T \geq 0, g_u \geq 0, g_{uu} \leq 0, w_m \geq 0, w_{mm} \geq 0, \delta_u \geq 0, \delta_{uu} \geq 0$$

where, B= Present value of benefits from maintenance, *T*= Service life of the vessel, *u(t)*= Vessel's utilisation at t, *g(u(t))*= net revenues excluding of maintenance cost, *m(t)*= Maintenance services at t, *w(m(t))*= Cost of maintenance, *S(T)*= Scrap value of vessel at T, *δ(u(t))*=Rate of physical depreciation including obsolescence, *f(t)*=Effectiveness of maintenance technology, a quality of maintenance index, *ξ(t)*=a function of small technological advances in equipment that reduce the benefits of maintenance, r= interest rate, *W*= Expected cost of overhauling the vessel, hence the cost of Special Survey and Intermediate survey, C_d = Cost of disposing the vessel at the end of its useful life, e.g. a ballast trip to reach its scrapping yard.

Equation 1 shows that the present value of benefits of maintenance is affected by the total discount net cash flow from operation (see equation 1), starting from period 0 until it is scrapped at *T* (if the vessel's age is less than its useful time), plus the present value of its scrap value *S* at *T*. Equation 2 shows the derivative of *S* over time, which depends on the effectiveness of maintenance technology, the quantity of maintenance work and lastly on the depreciation of the vessel and on small technological advances which may reduce the value of the vessel. Equation 3 sets a condition that the scrap value price must exceed disposal costs. Finally Equation 4 takes into account the cost of overhauling, that is the cost of the major surveys such as the special survey and dry-dock. Note that the subscripts are first and second order derivatives.

Next we construct the Lagrangian in order to solve (1) [1]:

$$L = \{g(u) - m)\}e^{-rt} + \lambda[fm - \delta(u) - \xi] + \mu[S(T) - C_d] + v_1[W - m] + v_2 m + \eta_1 u \qquad (5)$$

where λ, μ, ν_1, ν_2, η_1 are functions of time. In order to solve for *m(t)* we use the first order conditions. It should be said, however, that the solution of *m(t)* would greatly depend on the particular maintenance policy case. This can be divided into the following five cases:

Case 1: **Neither overhauling nor lay-up** $\nu_1=0$, $\nu_2=0$, $\eta_1=0$
Case 2: **Stopping and Scrapping** *m(t)*=0, *u(t)*=0, $\nu_1=0$, $\nu_2>0$

[1] Bitros, G. C. (2000), "Economic Replacement Theory, Recovered and Extended", Athens University of Economics and Business, Department of Economics, Unpublished mimeo.

Case 3: **Stopping and Depleting** $m(t)=0, u(t)>0$ $\nu_1=0, \nu_2>0$
Case 4: **Lay up** $m(t)\geq 0, u(t)=0,$ $\nu_1=0, \nu_2=0$
Case 5: **Overhauling** $m(t)=W\,u(t)\geq 0,$ $\nu_1>0, \nu_2=0$

Note that Case 3 is not acceptable, because there are stringent regulations imposed by the IMO, Classes, and lastly PSC authority act as a barrier for substandard vessel to be chartered because of the detention risk. However, cases 1, 2, 4, and 5 are feasible and although the optimal solution is found separately for every solution, these are interrelated. However, the analysis can become very tedious when combining all four cases together. Hence, we solve (1) under different restrictions set on the Lagrangian in equation (5), where a different set of conditions must be obeyed. In particular we are interested in the ones for optimal utilisation and maintenance, where it is required that:

Case 1: $$g_{u(t)} - w_{m(t)} + [f(t) - \delta_{u(t)}](e^{-r(T-t)} + \mu) = 0 \qquad (6)$$

Case 2: since m=0, maintenance is independent

Case 3: again m=0. As in case 2 any maintenance work is very restricted.

Case 4: Here maintenance will depend on market conditions as well as to the extent of the physical depreciation of the vessel.

Case 5: Since overhauling is fixed by class regulations maintenance will depend on W, the cost of overhauling which a necessary cost in order to obtain all the class documents.

In equation (6) T is determined by a separate equation. It is now possible to set Ship Maintenance Expenses as a function of the following variables:

$$w(m(t)) = f\{\ \overset{+}{u(t)}\ ,\ \overset{+}{\mathrm{W}}\ ,\ \overset{+}{T}\ ,\ \overset{+/-}{r}\ \} \qquad (7)$$

Note that W will depend on a number of factors that are related to the ship and the company policy, let alone the regulatory restrictions. In addition, note that *f(t)* was set to a constant, and T denotes actual AGE in the econometric model. In the following section, we discuss utilisation as well as other factors, which affect W and maintenance expenses. Note, that nowadays maintenance does not take place only during surveys, but on an on-going basis that satisfies the preventive nature of ISM. Hence there are a number of factors that can be included in the econometric model. Their theoretical explications are discussed thoroughly in the next section.

3. Data, definitions and measurement of variables

The empirical model should include the following variables that are needed for the cross sectional analysis:

$$y = \sum_{i=1}^{3} y_i = c + \sum_{i=1}^{11} a_i X_i + \sum_{i=1}^{10} \gamma_{1i} CO_i + \sum_{i=1}^{5} \gamma_{2i} F_i + \sum_{i=1}^{7} \gamma_{3i} T_i + \sum_{i=1}^{10} \gamma_{4i} CS_i +$$
$$+ \gamma_5 HTS + \gamma_6 EC + \sum_{i=1}^{10} \gamma_{7i} YA_i + \gamma_8 DD + \gamma_9 SS + \gamma_{10} DD1 + \gamma_{11} CG + \gamma_{12} TC +$$
$$+ \gamma_{13} FIX + \sum_{i=1}^{3} \gamma_{14i} W_i + \gamma_{15} CC + \varepsilon \qquad (8)$$

where, Maintenance Expenses (y) include: y_1 = Stores, y_2 = Spares, y_3=Repairs and Surveys. Also, X_1 = Age, X_2 = Size in Dead-weight tones (DWT), X_3=Average number of crew during 1999, X_4 = Number of Previous Owners, X_5 = Years in Present Ownership, X_6 = Years since last survey took place, X_9=Size in Break Horse Power (BHP), X_{10} = Number of Cranes on vessel, CO_i=Shipping Owning/ Managing Company - One dummy variable for each company, F_i = Flag - One dummy variable for each flag, T_i = Vessel Type - One dummy variable for each type, CS_i = Classification Society - One dummy variable for each society, HTS = Vessels built with High Tensile Steel, EC=Vessels built without Epoxy Coating, YA_i = Yards where maintenance took place in 1999, DD = Vessels that had a Dry-Dock or an Intermediate Survey during 1999, SS= Vessels that took a Special Survey during 1999, DD1= Vessels that took an other major repair or survey in a yard during 1999, CG=Vessels with Cargo Gear. It can be used instead of X10. A number of Utilisation Factors are also used in the equation, as follows: X_7 = Days Off-Hire of each vessel during 1999, X_8 = Number of Fixtures of each vessel during 1999, X_{11} = Miles travelled during 1999, TC = Takes the value of 1 if the vessel was on Time Charter during 1999, FIX = Takes the value of 1 for each vessel that had more than 20 fixtures during 1999, W_i = Waterway Utilised, CC = Ratio of Winter to Summer Climatic Conditions.

The collection of data for 112 ships took place in Piraeus and London during August and September 2000, by contacting directly 10 ship managers. They were asked to fill a questionnaire and provide additional information for every vessel's maintenance expenses for the year 1999. Companies in the sample differed in terms of size, average age of the fleet, as well as in terms of ship's type. Most of the data collected satisfy the definition of each factor. The only case for which a proxy had to be created was the utilisation rate.

The collection of maintenance expenses had to be taken from each vessel's profit and loss accounts. Having to deal with primary data, we had to ensure that the maintenance expenses provided by the vessels' P&L accounts was accurate. The most common problem was that the 1999 accounts included some of the surveys expenses that occured in previous years or if the vessel had a special survey during 1999 its cost was allocated for the next 5 years and only part of the total cost was included in 1999. Any adjustment we made was to reflect the *realised maintenance cost of every vessel during 1999* and asked the personal help of the companies managers to carry out the adjustments.

As far as the total maintenance expenses are concerned, we prepared an exhaustive list of categories that are related to maintenance repairs, so that we would be given all the expenses from their P&L accounts. Table 3 shows the three major categories in the P&L that add up to total maintenance cost. According to this we calculated the total maintenance cost and allocated each cost according to the three major categories: Stores, Spare Parts, and Repairs and Special Surveys.

Table 3: Example of a typical P&L accounts on Maintenance Expenses

- STORES
    - DECK STORES
    - ENGINGE STORES
    - ENGINE CHEMICALS
    - FORWARDING EXPS FOR STORES
- SPARES
    - PAINTS
    - SAFETY EQUIPMENT
    - SLOPES
    - SPARE PARTS FOR REPAIRS
- REPAIRS/ SPECIAL SURVEYS

Stores expenses refer to the amount spent to consumable supplies. Necessary equipment replacement is allocated to spare expenses, while repairs and surveys expenses reflect the cost of maintenance work either carried out in a yard or on board (personal communication). The most common subgroups under each of the three categories are shown in table 3. All in all, it was very important to have a clear definition, but also followed the practical advice from technical shipping experts to include all expenses related to maintenance work.

As far as age is concerned, all the ships in the sample were built prior to 1999. The size of vessels is measured in Dead Weight Ton (DWT). In addition, information was asked for the Main Engine Break Horse Power (BHP) because it may act as a proxy for size, since bigger vessels carry main engines with a higher BHP. However, there can be controversy in comparing different types of ships. Some vessels are smaller in terms of DWT because of the type of cargo they carry. For example LPG carriers have a very complicated cargo system of pipes and tanks for converting the Gas cargo into liquefied form and probably maintenance expenses may be significantly higher than the simpler constructed vessels such as bulk carriers. Yet they are much smaller in DWT than bulk carriers. Hence, we also test whether BHP can capture the interactive effect of the ship's type and size together, otherwise DWT is used.

The number of cranes on board each vessel may affect maintenance costs. The years in present ownership of each vessel as well as the number of previous owners is included in the empirical model, to test for the significance of these variables. Finally, the years since the last survey took place were calculated in order to investigate if vessels that took their last special survey recently (say in 1998), present relatively lower maintenance expenses in 1999.

Dummy variables were used to test the significance of the Ship Type, flag, classification category and yards where maintenance took place. The flag distribution among ships, can been seen in table 2. The predominant flag in the sample is Greek, which leads by 42%. Concerning the ship's class in the sample, out of 9 classes, Lloyds Register dominates in the sample by 33%, followed by ABS at 21% and DNV at 15%. The rest of classes account for 31%, where no individual class takes up more than 7%.

In order to capture the vessel's history, we asked if the ship was built with high tensile steel. We use a dummy for this factor, and another dummy if epoxy coating on cargo and ballast tanks was applied during the construction. Lastly, we asked if the vessel had any intermediate or special survey during 1999. The answer could be either "DD" (intermediate survey), "SS" (Special Survey), "Other" (other maintenance work that was done in yards), or "NO" (no maintenance work at all took place in a yard). Hence we use three (3) dummies for the first three options and we let the "NO" answer be the base.

It is worth mentioning that we did aim to collect data on past accidents by asking specifically for the accident record of each vessel. However, these records were not provided on the grounds of company policy.[1] In addition, direct expenses, for repairing damaged vessels, were not included in the maintenance cost category and in no other part of the P&L account because these are paid by the insurance cover. A dummy variable was also used in order to capture company policy and its influence on maintenance costs.

The utilisation rate is measured through the number of fixtures, off-hire days, average speed, miles and main routes travelled by each vessel. Companies are not able to provide data on the number of miles travelled since these are rarely recorded. However the following approximation can be used.

$$\text{Miles} = \text{Total days at sea x average speed per hour x 24.} \qquad (9)$$

Since days off hire reflect time spent for repairs, breakdowns, holidays and time waiting for cargo, these, together with the total port time can be subtracted from 365 to calculate the total days at sea. To determine total port time, number of voyages and average port

[1] The collection of confidential information proved to be more challenging than we initially expected. Shipping companies are very conservative in nature, because of the harsh competitive environment, and because of the close circle of the business where everyone knows each other's business.

time of each should be multiplied, where port time is defined as the days required for a vessel to load and discharge cargo. We assume that this time is standard for each type of vessel. Finally, since speed is measured in knots (miles/hour), it is multiplied by 24 so as to assess miles travelled per day.

Being aware of the routes that each vessel travelled and the period she realised them, it was easy to assess whether she operated in summer or winter climatic conditions. To clarify this, note that we used the concept according to the Lloyd's maritime atlas load line zones. The implication of this is that in the winter zone, the vessel is lighter and carries higher risk of cargo movement. In addition, it is likely to suffer more in winter conditions. For our purposes, the international load lines of Lloyd's maritime atlas were used so as to define whether each ship operated either in winter seasonal area, or in the summer zone. For example, a vessel travelling from Central America to the Baltic Sea in the winter, she first crosses through the North Atlantic Summer zone, where summer load line climatic conditions prevail[1]. Secondly she passes through the North Atlantic winter seasonal zone where winter climatic conditions prevail for the autumn and winter periods and finally it reaches the Baltic Sea where the climatic conditions follow the latter. Since nearly all of the vessels in the sample are over 100m, most of them have a similar trading pattern with reference to the climatic conditions within which they operated. Hence, there was no significant variation of the sample data and as a result led to collinearity problems. As an alternative we categorised the various routes travelled by each vessel, as in Talley W. (1996), where he described the type of waterway utilised as either coastal, inland or ocean. Hence in the above example the vessel used an ocean waterway. As it was expected that the larger bulk carriers and tankers exhibit less number of fixtures, mostly in transocean and long haul coastal voyages, whereas the handy sized bulk carriers, the general cargo vessels and the LPG's demonstrate greater number of fixtures in inland and short haul routes.

4. Empirical results

Different estimation results are obtained for the whole data, age and type of vessel and for each of the categories of maintenance expenses. The following log-linear model is estimated:

$$\ln y = c + \sum_{i=1}^{5} a_i \ln X_i + \sum_{j=1}^{6} \beta_j X_j + \sum_{n=1}^{15} \gamma_n dummy_n + \varepsilon \qquad (10)$$

In the above model the variables X_4, X_5, X_6, X_7, X_8 and X_{10}, can not be expressed in logs since they often take the value of zero.

Analysis of Total Maintenance Expenses

Table 4 shows the Ordinary Least Squares (OLS) estimates of equation (10). The results are consistent with the sign expectations outlined above except for the coefficient of the variable LX11 ($\log X_{11}$) that denotes the miles travelled. This means that the aforesaid variable can not capture the utilisation rate of the vessel, which according to a priori expectations should have a positive effect on maintenance expenses. Two reasons may be put forward for this. First, because off hire days, which have a negative effect on maintenance expenses, as can be seen by the coefficient of X7, are included in (10). Second, because (10) shows the miles travelled for each vessel irrespective if it took repairs in a yard or not. As a result miles travelled as determined from (10) have a negative effect on maintenance expenses due to the fact that a vessel that took repairs into a yard has significant higher expenses than a vessel that took repairs on board while travelling. In

[1] Note that according to Lloyd's maritime atlas, summer climatic conditions always stand for vessels over 100m in the North Atlantic Summer zone, irrespective of the season.

other words the former vessel has more expenses but less miles travelled since it was in a yard for a significant period of time.

Therefore the following equation for utilisation is estimated in order to achieve more concrete results.

Miles = (365-Total Port Time) x average speed per hour x 24 x DS (11)

where, *DS= DD+SS+DD1*

In this way, equation (11) can be used as an approximation for the utilisation rate in terms of miles travelled. It captures the effect of utilisation on maintenance expenditure for the vessels that went through either a special survey, dry-dock or other major repairs or surveys. The maintenance expenses among the vessels that did not take repairs into a yard are not significantly different.

Furthermore, in the above analysis, yards where maintenance repairs took place have been distinguished into high cost yards and low cost yards. The first category includes Greece, Holland, Italy, Turkey and Japan (YA11) which according to our sample are the most expensive yards. On the other hand the second group of yards embodies China, Korea, Curacao, Romania and Singapore (YA12). As mentioned before the cost of raw materials and the economic conditions prevailing in each country together with the subsidies donated by Governments determine the tariff of each yard. As expected, the sign of the coefficient of variable YA11 is positive.

Table 4: Total Maintenance Expenses - Empirical Results

Regressor	*Coefficient*	*Standard Error*	*T-Ratio*	*[Prob]*
C	13.771	1.935	7.117	[.000]
LX1	0.379	0.055	6.844	[.000]
LX2	0.250	0.043	5.754	[.000]
LX11	-0.437	0.165	-2.651	[.009]
X7	-0.005	0.001	-3.578	[.001]
CS8	0.566	0.148	3.824	[.000]
CS9	-0.819	0.214	-3.821	[.000]
YA11	0.184	0.109	1.694	[.094]
F5	0.350	0.109	3.213	[.002]
F2	-0.415	0.191	-2.168	[.033]
DD	0.311	0.100	3.121	[.002]
SS	0.324	0.108	2.994	[.003]
DD1	0.442	0.167	2.654	[.009]
CO1	0.498	0.136	3.669	[.000]
CO8	0.442	0.151	2.931	[.004]
Number of observations		112		
S.E. of Regression		0.351		
R-Bar-Squared		0.704		
F-stat. F(14, 97)		19.904 [0.00]		
Functional Form CHSQ (1)		0.050 [0.823]		
Normality CHSQ (2)		0.111 [0.946]		
Heteroscedasticity CHSQ (1)		1.7684 [0.184]		

Notes:

1. For abbreviations and definitions of variables see appendix
2. S.E. = Standard Error of Regression; F-Stat tests for the joint significance of the explanatory variables in the regression model; Functional form is Ramseys RESET test for functional form, distributed as $\chi^2(1)$; Normality is the Bera-Jarque test for norality of the residuals, distriburted as distributed as $\chi^2(2)$; Heteroscedasticity is the White test for heteroscedasticity distributed as $\chi^2(1)$. Values in square brackets next to the diagnostic tests are p-values (exact significance levels).

Finally in the above results we can note that maintenance expenditure is significantly different among companies and is also affected by the flag factor and the classification society factor, but since this is not the final model we will not refer extensively to them.

Next, the variable LX13 was added, denoting the logarithm of the utilisation rate as determined by (11). The results are shown in Table 5. Clearly, the results leave much to be desired. The coefficients of the variables shown above have all the postulated signs and are significant at the 5% level of significance. The explanatory power of the model is quite strong as can be seen from the R bar squared value of 0.689. Moreover, the diagnostic tests indicate that there are no problems of non-linearity, non-normality or heteroscedasticity.

Thus, it seems that utilisation affects positively the maintenance expenses of each vessel. More precisely the elasticity of maintenance expenditure with respect to utilisation rate is 0.032. That is to say that for each unit change in utilisation, maintenance expenses increase by 0.032. Furthermore, the maintenance cost elasticities with respect to age (LX1) and dead-weight tones (LX2) are also positive and take the values of 0.329 and 0.190, respectively. Age seems to have the highest impact in comparison to utilisation rate and vessel size in determining ship repair costs. As far as the rest of the variables are concerned it can be observed that the off-hire days have a very small negative effect on the dependent variable. More specifically, changes in the off-hire days alter expenses only by 0.5% times X7. This means that the elasticity varies with X7.

In addition, it can be noted that the independent variables company1 and company10 play a significant role in determining ship maintenance expenditure. This may have a number of interpretations. Firstly, the management of these companies may be less effective than the remaining ones in terms of keeping the operating costs within the desired levels. This could be due to unskilled personnel or to inability to take the right decisions in the right time. Secondly, it could be due to the policy they follow in terms of extending the lifetime of the vessel so as to keep it long-term. Last but not least these companies may operate very complicated vessels such as LPG's or other chemical tankers which require unexpectedly high maintenance expenses. It was not the aim of this paper to compare companies but it was inevitable in obtaining a good fit.

Table 5: Total Maintenance Expenses - (variable LX13 included)

Regressor	*Coefficient*	*Standard Error*	*T-Ratio*	*[Prob]*
C	9.509	0.552	17.217	[.000]
LX1	0.329	0.056	5.826	[.000]
LX2	0.190	0.046	4.108	[.000]
LX13	0.032	0.008	4.087	[.000]
X7	-0.005	0.001	-3.670	[.000]
CS8	0.567	0.150	3.793	[.000]
CS9	-0.813	0.216	-3.756	[.000]
YA11	0.221	0.101	2.181	[.032]
F1	0.552	0.147	3.761	[.000]
F5	0.485	0.108	4.499	[.000]
CO1	0.399	0.137	2.909	[.004]
CO10	0.592	0.177	3.344	[.001]
Number of observations		112		
S.E. of Regression		0.359		
R-Bar-Squared		0.689		
F-stat. F(12, 99)		23.451 [0.00]		
Functional Form CHSQ (1)		1.968 [0.161]		
Normality CHSQ (2)		1.646 [0.439]		
Heteroscedasticity CHSQ (1)		0.952 [0.329]		

Notes: See notes in table 4

Furthermore, it can be noticed that two of the most common open registry flags, Bahamas (F1) and Panama (F2), affect positively the dependent variable y. These results are again in general agreement with theory, since open registry flags have less requirements and as mentioned before, most of their ships tend to be substandard ships which need further maintenance work.

Also, it can be noted that the Italian (CS8) and the Russian (CS9) classification societies have a positive and a negative coefficient respectively. This captures the fact that regulations imposed by each society, and in this case, by "*Registro Italiano Navale*" and "*Russian Maritime Register of Shipping*", have a significant effect on maintenance expenses, despite the fact that those examined, are all members of the International Association of Classification Societies (IACS). Finally, the high cost yards (YA11) as determined above have a positive coefficient of 0.221, which is again in agreement with a priori expectations.

In addition to the above, we performed separate analysis for each type of vessel in the sample. Furthermore, we estimated a model for all vessels that are less than 20 years old. The results provided a clear indication that analysing data in this way, could show which variables affect directly the aforementioned categories. However, the problem with this approach was that the small sample would render the results unreliable because of the low statistical power of the regression. Therefore, in order to enhance the power of the regression estimated, the general model in table 6 was used and additional variables were included that took into account the interaction effect of each category we wanted to test. The interaction effect would be included by multiplying the category dummy with the estimated variables in table 6 as well as with additional variables.

Table 6: Total Maintenance Expenses - Final model including interaction effects

Regressor	*Coefficient*	*Standard Error*	*T-Ratio*	*[Prob]*
C	8.947	0.565	15.843	[.000]
LX1	0.339	0.055	6.205	[.000]
LX2	0.229	0.049	4.726	[.000]
LX13	0.049	0.012	4.014	[.000]
X7	-0.005	0.001	-3.689	[.000]
CS9	-0.763	0.197	-3.867	[.000]
YA11	0.204	0.102	1.988	[.050]
CO1	0.438	0.126	3.481	[.001]
CO10	0.555	0.159	3.490	[.001]
F5	0.470	0.098	4.791	[.000]
ALX1	0.089	0.038	2.349	[.021]
ALX13	-0.032	0.013	-2.394	[.019]
AF1	0.645	0.162	3.978	[.000]
BCCO8	1.102	0.325	3.395	[.001]
BCF1	-1.427	0.385	-3.711	[.000]
GCYA11	0.286	0.166	1.718	[.089]
LPGCS8	0.653	0.162	4.043	[.000]
Number of observations		112		
R-Squared		0.795		
S.E. of Regression		0.315		
R-Bar-Squared		0.761		
F-stat. F(11, 70)		23.156 [0.00]		
Functional Form CHSQ (1)		0.616 [0.432]		
Normality CHSQ (2)		1.495 [0.473]		
Heteroscedasticity CHSQ (1)		1.335 [0.248]		

Notes: See notes in table 4

The latter were variables that were found significant when we initially estimated each category separately. Therefore we introduced five additional dummies each of them multiplied by the aforesaid variables. We included one dummy, which took the value 1 for vessels under twenty years of age and four dummies which took the value of 1 for each of the following categories: bulk carriers, LPGs, general cargoes and tankers.

Including additional dummies in the general model has three major implications. The first one is that if there is an interaction effect with an existing variable we can see if the interaction effect of a category differs significantly from the result of the general model in table 5. Secondly, if there is an interaction effect with a variable that was not previously estimated, we infer that this applies only to the specific category of which the effect takes place. Therefore, the model is enhanced in two ways, as we do not only compare significant differences among existing variables but also capture the effect of other variables that were initially found insignificant. Lastly, the third effect of this approach is that some of the estimated variables in table 5 may prove insignificant alone and significant when combined with a specific category. Therefore, the inclusion of the category with the previously estimated variable produces superior results. In effect it provides the additional and more specific information. In other words the presence of a significant variable in table 5 may be due to its high relevance with a specific category.

The results of the above analysis are shown in table 6. One can note that seven additional variables appear in the model, significant at the 10% significance level, and as result the explanatory power of the model has increased. More specifically R bar squared has increased by 7.1% and the standard error of regression has fallen to 0.315.

It can be noticed that the elasticity of maintenance expenses with respect to vessels under twenty years of age, which is shown by the coefficient of variable (ALX1), is greater by 8.9%. The total effect of age on maintenance cost for vessels less than twenty years old is 0.428, which is the sum of coefficients of variables LX1 and ALX1. The effect of age on maintenance expenses is stronger when vessels are under 20 years old because their expected useful life is at least 20 years. Therefore scheduled maintenance expenses increase as age increases the ship's physical depreciation. However, as vessels exceed the 20 years barrier and especially the 25th one, shipowners are more cautious in the maintenance expenses schedule since the ship's commercial opportunities are delimited by competitors' younger fleet.

On the other hand the elasticity of maintenance expenses with respect to utilisation is reduced for ships under twenty years of age by 3.2%. This a quite discrete result since, as it is expected, the costs due to utilisation should increase at a relatively higher rate for vessels that have overcome the 20th year of age. This is due to the fact that the vessel and especially the machinery parts are less effective when reaching a certain age and require additional maintenance. This can be proved also by the higher levels of fuel consumption that old vessels present.

Considering table 6 we notice that the Bahamas flag dummy does not appear alone, as it did in table 5, but it is significant in conjunction with the bulk carriers dummy and the age dummy. This is an empirical result that proves that the effect of the Bahamas flag is significant either for bulk carriers or for vessels under twenty years old. More specifically, a bulk carrier's shipowner can achieve great economies when he registers his ships under the Bahamas flag, an effect which can be significantly reduced if the vessels are below twenty years of age. This effect can be shown by the coefficients of the variables BCF1 and AF1 that take the values of –1.427 and 0.644 respectively. As mentioned before, the effect of the flag may have a longer term, because it will be easier to understand whether accidents and Port State detention, which increase SME, are related to the flag element.

Along the same lines it is shown that the classification society 8 (RINA) existed in table 4 solely because of the significant effect it had on the maintenance expenses of LPG carriers. This is probably due to the fact that almost all of the vessels in our sample that are under the Italian society are LPGs, which have relative higher expenses. We should bear in mind that the structure of the LPG's is the most complicated in the sample and regulations are stricter because of the type of cargo. It should be expected that satisfying safety regulations and minimising the risk of port detention might have led managers to increase maintenance expenses during 1999.

Furthermore we can observe that the effect of the high cost yards in our sample is oversized for general cargo vessels. This explains that the repairs and surveys in these yards cost more for the general cargo vessels. In particular, it may be due to the existence of cranes and other specific features that require further repairs while in yard, so as to continue working in satisfactory levels. Moreover these vessels can carry a great range of products from sulphur to masses of steel that can cause damage on the hull which can be repaired only in a yard.

Finally in comparison with the results in table 4 it can be noticed that an interaction variable is introduced which captures the effect that the variable BCCO8 has on maintenance expenses. Specifically, it is found that company 8 shows increasing expenses on bulk carriers. This is due to the fact that this company specialises in general cargo vessels and has not much experience on bulk carriers; as a result it faces increasing costs on the latter.

Analysis of Stores, Spares and Repairs and Surveys expenses

In the ensuing analysis we examine the variables that determine each of the categories of ship maintenance expenses shown in Table 3; that is, stores, spares and repairs and surveys expenses. Tables 7, 8 and 9 summarize these results.

Table 7: Stores only

Regressor	*Coefficient*	*Standard Error*	*T-Ratio*	*[Prob]*
C	8.286	0.709	11.688	[.000]
LX1	0.218	0.070	3.104	[.002]
LX2	0.174	0.061	2.844	[.005]
LX13	0.015	0.009	1.654	[.101]
X7	-0.005	0.002	-3.012	[.003]
CO1	1.648	0.151	10.911	[.000]
CO2	0.911	0.167	5.467	[.000]
CO8	-0.505	0.183	-2.765	[.007]
CO10	0.600	0.225	2.665	[.009]
F2	0.461	0.247	1.869	[.065]
CS8	0.505	0.191	2.647	[.009]
T2	0.263	0.126	2.091	[.039]
YA2	0.274	0.140	1.964	[.052]
Number of observations		112		
S.E. of Regression		0.458		
R-Bar-Squared		0.732		
F-stat. F(12, 99)		26.331 [0.00]		
Functional Form CHSQ (1)		1.944 [0.163]		
Normality CHSQ (2)		1.466 [0.480]		
Heteroscedasticity CHSQ (1)		2.031 [0.154]		

Notes: See notes in table 4

Table 8: Spare Parts only

Regressor	*Coefficient*	*Standard Error*	*T-Ratio*	*[Prob]*
C	10.287	0.203	50.752	[.000]
LX1	0.416	0.090	4.614	[.000]
LX13	0.039	0.009	4.364	[.000]
T1	-0.470	0.143	-3.291	[.001]
F5	0.541	0.140	3.868	[.000]
CS4	-0.437	0.231	-1.892	[.061]
CS9	-1.888	0.313	-6.033	[.000]
EC	0.522	0.311	1.676	[.097]
Number of observations		112		
S.E. of Regression		0.514		
R-Bar-Squared		0.636		
F-stat. F(7, 104)		28.760 [0.00]		
Functional Form CHSQ (1)		1.390 [0.238]		
Normality CHSQ (2)		0.214 [0.898]		
Heteroscedasticity CHSQ (1)		1.431 [0.231]		

Notes: See notes in table 4

Table 9: Repairs and Surveys only

Regressor	*Coefficient*	*Standard Error*	*T-Ratio*	*[Prob]*
C	8.038	0.874	9.191	[.000]
LX1	0.338	0.098	3.458	[.001]
LX2	0.246	0.072	3.395	[.001]
LX13	0.068	0.012	5.527	[.000]
X7	-0.005	0.002	-2.226	[.028]
HTS	0.488	0.129	3.785	[.000]
CO8	1.016	0.226	4.489	[.000]
CS4	-0.541	0.297	-1.823	[.071]
CS6	-0.365	0.139	-2.634	[.010]
CS8	0.785	0.243	3.226	[.002]
CS9	-0.633	0.343	-1.848	[.068]
YA1	-0.513	0.177	-2.892	[.005]
YA3	-0.605	0.318	-1.905	[.060]
Number of observations		112		
S.E. of Regression		0.568		
R-Bar-Squared		0.503		
F-stat. F(12, 99)		10.366 [0.00]		
Functional Form CHSQ (1)		0.253 [0.987]		
Normality CHSQ (2)		1.502 [0.472]		
Heteroscedasticity CHSQ (1)		0.018 [0.893]		

Notes: See notes in table 4

At this stage we should point out the most interesting results. Firstly, as far as stores are concerned, it can be noticed that the company factor plays a major role in determining vessel maintenance expenses. Especially in the case of the first company, the coefficient takes the value of 1.648, which is by far the highest we have seen until now. At this point we must mention that company 1 owns a fleet of LPG's which, as mentioned before, have the most complicated structure. Here it is proved that the complexity of these vessels results to really high expenses in terms of stores. Furthermore the coefficients of the remaining companies in table 6 are also relatively high, strongly indicating that the amount spend on stores depends mostly on company policy. The factors of age, size and utilisation present a similar pattern with the whole data analysis. In addition, it can be noticed that some other factors such as the Cyprus flag, the Italian classification society, the middle-sized bulk-carriers and the Greek yards affect stores positively.

In terms of spares, two are the most noticable points. Firstly, the fact that the size variable does not play any significant role in measuring spares outlay and secondly that the factor of epoxy coating appears to have a significant effect in the latter. Specifically, vessels that did not have epoxy coating applied to them when built present relatively higher spares expenses. Since paints are included in the category of spares, as can be seen in table 3, it can be easily concluded that higher spares expenses are a result of the additional painting required on the surface of the cargo and ballast tanks. Regarding the remaining significant parameters the pattern is more or less the same with the previous analyses.

Lastly, as far as repairs and surveys expenses are concerned, the factor of high tensile steel appears to have a significant positive effect on them. This means that the vessels which were built with high tensile steel have relatively higher repairs and surveys costs since the amount of this type of steel has to be replaced so as to compromise with the regulations imposed by the classification societies. The latter, as can be seen from table 9, have a significant role in measuring surveys costs since each society applies different standards in order to appraise the seaworthiness of the each vessel. More specifically *"Germanischer Lloyd"* (CS4), *"Lloyds Register of Shipping"* (CS6) and *"Russian Maritime Register of Shipping"* (CS9) have a negative effect whereas *"Registro Italiano Navale"* (CS8) has a positive effect. The variables of age, size and utilisation appear in the equation in a similar manner as in the earlier analyses, whilst company's eight coefficient takes the value of 1.016 and the China (YA1) and Holland (YA3) yard's coefficients take the values of –0.513 and –0.605, respectively.

5. Conclusions

This paper on ship maintenance expenses had three main objectives. First to inestigate a neglected empirical area of shipping. The introduction of ISM and the increased presence of Port State Authorities have made shipmanagers more conscious about the maintenance schedule of their fleet. In effect, there is a change in their approach on the amount and quality of maintenance work. Nowadays, the frequent, preventive, nature of maintenance work becomes as important as the major surveys. Our analysis provided a framework on how regular maintenance should be studied, how the effect of major surveys could be assessed on SME.

Secondly, as an empirical study we hope it can show some direction to future research on ship maintenance expenses. At first place, a larger sample over 250 vessels would include a larger number of vessel types and improve the estimable models. For example, our sample, which is 112 vessels, has only 6 tanker carriers of which 3 are product tankers while the rest are crude oil tanker carriers. In this category we were unable to estimate a model. Similarly, one could enhance the current analysis by including additional variables. Another way to improve the research is to expand the study into time series in order to evaluate the long-term effect of the factors estimated in the model and secondly, to allow for additional variables to enter the estimated model, which can take significance in a time series framework. For example, our analysis did not take into account variables such as the interest rate, and market rates, like the freight, second-hand, scrap, new-buildings and scrapping rates.

Lastly, since this research has dealt with primary data, it can provide guidance and food for thought about the difficulties and the amount of time needed to collect data for other variables that may produce better results. For example, the extraction of the utilisation rate needed data that required us to ask for routes, number of Off-hire days and number of fixtures. Most shipping companies were reluctant to provide this information.

Nevertheless, we managed to build a theoretical model, and an empirical model which fitted well the data. In addition, our analysis studied separately a number of categories and all results highlighted the three key factors that explained SME in 1999; that is, age, size and utilisation of the vessel. The effect of age increases for vessels under twenty years of age, while the utilisation effect increases for vessels over the aforesaid age. We also found that the total maintenance expenses were inelastic with respect to these three factors. Hence, although they affect positively maintenance cost, the proportional increase in expenses is less than the proportional increase in age, size or utilisation. If the increase in expenses was greater than the proportionate increase in age, we would find increasing diseconomies with respect to age. All in all, we did not find such diseconomies because the elasticity of age with respect to maintenance expenses was 0.339 for the whole sample and 0.428 for vessels that are less than 20 years old.

Practical implications of the analysis include: As far as maintenance decision-making is concerned the yard where major repairs must be carried out should be considered. Given our sample, we point out a number yards that raise SME more than others. When we estimated separate models for the stores, spares and repairs expenses, we found that ships, which were not painted with epoxy coating on cargo and ballast tanks at construction, exhibited increased spares maintenance expenses. Vessels that were built with high tensile steel resulted also in higher Repairs/Surveys expenses, because of the need to replace the old thin steel with new one. Interestingly, in the estimated model for stores, the effect of company dummy is the most apparent one than anywhere else. It would be here where most likely company policy could have more control on maintenance expenses given the new regulations, even though it may be the case that it could reduce the quality and standard of maintenance.

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Appendix

List of Abbreviations

ABS:	American Bureau of Shipping
AMSA:	Australian Maritime Safety Authority
BC:	Bulk Carrier
BV:	Bureau Veritas
CCS:	China Class Society
DNV:	Det Notske Veritas
DWT:	Dead Weight Ton
GL:	Germanischer Lloyd
IACS:	International Association of Classification Societies
ICS:	International Chamber of Shipping
ISF:	International Shipping Federation
ISM:	International Safety Management Code
KRS:	Korean Register of Shipping
LPG:	Liquefied Petroleum Gas
LRS:	Lloyd's Register of Shipping
NKK:	Nippon Kaiji Kyokei
PSC:	Port State Control
RINA:	Registro Italiano Navalo
RMRS:	Russian Maritime Register of Shipping
R&M:	Repairs and Maintenance
SME:	Ship Maintenance Expenses

List of Variables

Y:	Total Maintenance Expenses	CS1:	ABS
Y1:	Stores	CS2:	BV
Y2:	Spares	CS3:	DNV
Y3:	Repairs and Surveys	CS4:	GL
X1:	Age	CS5:	KRS
X2:	DWT	CS6:	LRS
X3:	Number of Crew	CS7:	NKK
X4:	Number of Previous Owners	CS8:	RINA
X5:	Years in Present Ownership	CS9:	RMRS
X6:	Years since last survey took place	CS10:	CCS
X7:	Days Off-Hire	HTS:	High Tensile Steel
X8:	Number of Fixtures	EC:	Epoxy Coating
X9 :	Break Horse Power (BHP)	YA1:	China's Yard
X10:	Number of cranes	YA2:	Greece's Yard
X11:	Miles (off-hire days included)	YA3:	Holland's yard
X12:	Miles (off-hire days not included)	YA4:	Italy's Yard
X13:	X12 x DS	YA5:	Japan's Yard
CO1:	Company 1	YA6:	Korea's Yard
CO2:	Company 2	YA7:	Curacao's Yard
CO3:	Company 3	YA8:	Romania's Yard
CO4:	Company 4	YA9:	Singapore's Yard
CO5:	Company 5	YA10:	Turkey's Yard
CO6:	Company 6	YA11:	YA2+YA3+YA4+YA5+YA10
CO7:	Company 7	YA12:	YA1+YA6+YA7+YA8+YA9
CO8:	Company 8	DD:	Dry Dock
CO9:	Company 9	DD1:	Other
CO10:	Company 10	SS:	Special Survey
F1:	Bahamas Flag	DS:	DD+DD1+SS
F2:	Cyprus Flag	CG:	Cargo Gear
F3:	Greek Flag	TC:	Time Charter
F4:	Malta Flag	W1:	Coastal
F5:	Panama Flag	W2:	Inland
T1:	BC1 (0-45000)	W3:	Ocean
T2:	BC2 (45000-80000)	CC :	Winter/Summer
T3:	BC3 (80000-175000)	A:	Age <=20
T4:	General Cargo	BC:	Bulk Carrier
T5:	LPG	GC:	General Cargo
T6:	Tanker	LPG:	LPG
T7:	Oil & Asphalt	TA:	Tanker